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THE RIVER SYSTEM OF CONNECTICUT[1]

THE tendency of the modern school of physiographers seems to be to ascribe little importance to geological structure planes as a factor in determining the position and the orientation of water courses. In an earlier period greater attention seems to have been accorded to this condition, and quite apart from the purely theoretical conceptions of the closet geologists many valuable observations were placed upon record. Th. Kjerulf, the former Director of the Geological Survey of Norway, remarked the regularity in the arrangement of fjords, streams, and valleys as represented upon the map of Norway, and from this was led to believe that their directions corresponded to the faults in a system of dislocations. Daubrée[2] has furnished many examples of regular networks of stream channels which resemble the network produced by a number of intersecting series of parallel joint planes (*réseaux réguliers de cassures*), and the explanation of this correspondence he believed to be a causal one, the planes of separation, or jointing, being locally gaping where the streams adhere to the joint direction, but closed where they have been diverted from the course of the joint. Van Hise[3] has in a similiar way explained the zigzags of

[1] Published with the permission of the Director of the U. S. Geological Survey.

[2] DAUBRÉE: Géologie Experimentale. Paris, 1879, p. 361.

[3] VAN HISE: Trans. Wis. Acad. Sci., etc., Vol. X., pp. 556-560, 1895.

the small streams which enter the Wisconsin River at the "Dells" as due to a system of joints induced by the gentle folding of the rocks. That a more or less uniform system of joints exists in the rocks almost throughout the state of Wisconsin has been shown by Buckley's observations.[1]

So far as the writer is aware, the only detailed studies that have been made establishing the definite relationship of the stream channels of a region to its system of joints or faults, are those of Brögger[2] in the Langesund-Skien and Christiania regions of southern Norway, and that of the writer[3] in the Pomperaug Valley region of Connecticut. Of the elaborately faulted region which Brögger has studied, he states:

> It is not exaggerated when to my own astonishment I must state, as the final result of my observations in this region, that almost every valley, every cleft, is formed along a fault fissure. . . . . The significance of the faults for the formation of the valley straits is thus as profound as possible within the stretch of land described, since almost every cliff, every vale, every bay has been formed upon a line of dislocation; indeed the presence of clefts was for me, at the last, the surest index for the discovery of dislocations.[4] [Translation.]

Review of the geological structure of the Pomperaug Valley area of Connecticut. — Regarding the Connecticut area to which reference is made, it will be necessary here to review the study in order to make clear the generalizations with which this paper is especially concerned. It is now well known that the several areas of Newark rocks of the eastern United States are complexly faulted, and the many common structural peculiarities of the several isolated areas give rise to the belief that the forces which have produced the dislocations have affected, not the Newark rocks alone, but the larger region of which they are parts — the Piedmont plateau of the eastern United States.[5]

[1] BUCKLEY: Bull. 4, Geol and Nat. Hist. Surv. Wis., pp. 450–460, 1898.

[2] BRÖGGER: Nyt Magazin for Naturvidenskaberne, Vol. XXVIII, pp. 253–419, 1884. *Ibid.*, Vol. XXX, pp. 99–231, 1886.

[3] HOBBS: Twenty-first Ann. Rept. U. S. Geol. Surv., Pt. III, 1901, pp. 1–162.

[4] Op. cit., pp. 34, 342.

[5] Cf. DAVIS: The Triassic Formation of Connecticut, Seventh Ann. Rept. U. S. Geol. Surv., 1888, pp. 481–490.

The detailed study of the Pomperaug Valley area has developed the fact that a complex system made up of intersecting series of parallel nearly vertical joints and faults there divides the crust into a large number of orographic blocks, the smaller of which have dimensions of less than one hundred paces. The different throws along the numerous faults bounding these blocks have brought about a structure not unlike that of a mosaic from which the supporting base has been lowered and the individual stones been displaced by different amounts due to the inequalities of their lateral support. For the area as a whole, the joints and corresponding faults are embraced mainly in four series, the individual members in which trend N. ± 34° W., N. ± 55° E., N. ± 5° W., and N. ± 15 E. Series of faults less common for the area as a whole, but several of them numerous enough in its southern portions, have directions N. ± 33° E., N. ± 44° W., N. ± 61° W., N. ± 90° E. W., N. ± 20° E., and N. ± 25° W., the order being approximately that of frequency of occurrence. Of the more common series, those trending N. ± 55° E. and N. ± 34° W. are nearly normal to one another, as would be true of a pair of joint planes, but the larger throws within the region seem generally to have taken place along one of these planes (N. ± 55° E.) and one of the other prevailing directions (N. ± 5° W.). Aside from the regularity in direction observed to characterize the numerous faults and bring them into a number of parallel series, those faults of the same order of displacement are observed to be spaced also with noteworthy regularity. The smallest of the orographic blocks which could be measured, for convenience called the "unit" blocks, were found to be quite generally about 50 paces (150 feet) along the direction N. ± 55° E., and 100 paces (300 feet) along the direction N. ± 5° W.—the equivalent of two rhombic prisms in contact along one side. The larger, or "composite" blocks, which are of various orders of magnitude, are made up of the "unit" blocks and bordered by displacements of a higher order—greater throw. The fault intervals in the several series, and hence the shapes of the orographic blocks, are found to be closely related to the directions

of the prevailing and rarer fault series in a manner which is made clear by the diagram of Fig. 1. In this figure the shape of the unit orographic block—and of many composite blocks of several orders as well—is shown by the black and also by the stippled area. Two of the prevailing fault directions, N. ± 15° E. and N. ± 34° W. correspond to the longer and the shorter diagonals respectively of this unit block. The fault direction N. ± 33° E., which is the most common of those occurring in the southern Pomperaug area, corresponds closely to the longer diagonal of three unit blocks in contact along their longer side. Another of the series of faults characteristic of the same southern area and trending N. ± 20° E., corresponds to the longer diagonal of six unit blocks, two composite blocks like those just described placed in contact along their longer sides. The remaining directions of faults observed in the area are respectively the shorter diagonals of composite blocks three units long and two wide, four long and six wide, four long and seven wide, and two long and seven wide; though clearly in these latter instances, the relationships indicated in the diagram are less significant owing to the more complex nature of the composite blocks of which the fault directions are the diagonals. For a more important indication of the same relationship, which is observed in the actual composite blocks of the area studied, the reader must be referred to the original report.[1]

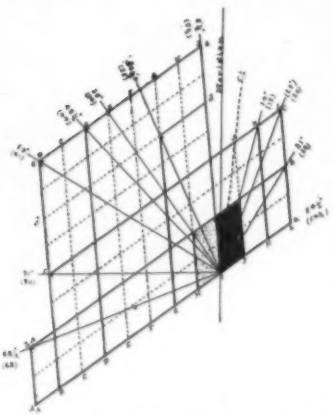

FIG. 1.—Diagram to illustrate the relationships existing between the shape of the "unit" orographic blocks and the directions of the fault series.

For the area in question the conclusion has been drawn that the earth's crust has been here subjected to compressive stresses,

[1] Loc. cit. pp. 117–120.

the resultant of which acted in a direction normal to the axis of Green Mountain folding (N. ± 80° W.), stresses which were relieved by dislocation along the planes of maximum shear, approximately 45° to either side of the direction of pressure, *i. e.*, S. ± 55° W. (N. ± 55° E.) and N. ± 34° W. The remaining common directions of fault planes (N. ± 15° E. and N. ± 5° W.) could be explained by a subsequent development of compressive stress acting along the initial direction; for in a region containing planes of separation at 45° to the direction of pressure, there would be a resolution of the stress into components acting along the planes of separation and along that diagonal of the blocks which is nearly normal to the pressure. The direction N. ± 15° E. corresponds to this diagonal of the joint block already formed, and the remaining direction N. ± 5° W. is the corresponding diagonal of two such blocks in contact. To explain these latter dislocations upon the same principle, it must be assumed that, owing to differences between the alternate joint planes of the same series, these double joint blocks acted to some extent as units. The fault directions characteristic especially of the southern portion of the area and disclosing such intimate relationships to the four generally prevalent ones, might be explained either by assuming that in the later compression of the jointed area composite blocks of different shapes, because composed of a different number or different arrangement of unit blocks, acted as units (whether due to the greater perfection of their bounding fault planes over intermediate ones, to the partial closing or healing of the intermediate faults, or to some other cause). In this case the maximum shear would be along the diagonal of the composite blocks, as would be the case in the unit blocks themselves, and it is shown in the report under review that these directions do correspond, *not only in direction, but also in position* with the diagonals of important composite blocks of the area. Under certain conditions, which may or may not have obtained in the area, planes of dislocation having the same directions might have been produced through the depression of the composite blocks subsequent to the jointing of the

area, since in this case also the tendency would be for blocks to rupture along the diagonals.

The oriented drainage of the Pomperaug Valley.—With this brief summary of the geological structure within the Pomperaug Valley area we may consider its drainage. It was found in studying the area that the streams, large and small, for considerable distances adhere with great fidelity to the directions of some of the prevailing faults, and that in many cases after being diverted from them, it was noted that they had returned persistently to the old direction. This correspondence of drainage lines to geological structure planes is far too close to be accidental. The four prevailing fault series diverge from their nearest neighbors at angles of about 39°, 20°, 29°, and 92°. A difference in angle between a fault direction and the general direction of a stream course equivalent to 7°, or about one third the smallest difference of angle between neighboring fault directions, would represent a divergence of one in eight, which would hardly be accepted by the eye as an indication of parallelism. It is not to be expected that the actual course of a stream will now be coincident with or even absolutely parallel to any fault direction, for there have unquestionably been many local conditions which have produced larger or smaller migrations of the river channels. Their general direction has, however, it would seem, been maintained despite the minor accidents which have marked their life-histories, and even under so revolutionary a change as complete reversal of drainage.

It was further shown in the investigation under review, that in the walls of crystalline rocks surrounding the Newark beds in the Pomperaug basin, the same adhesion of the water courses to the direction of the observed faults (extended) could be determined. It was hardly to be expected that these peculiarities would cease to be observable so soon as the immediate vicinity of the Newark basin was left behind, if it be indeed true that the dislocation of the area is due to a compression of the general region in which this area of Newark rocks and the much larger one of the Connecticut valley are included. Owing, however,

to the absence over the greater part of the surrounding area of widely different rocks in thin beds, the difficulties of locating fault planes are almost infinitely increased; and, indeed, except under especially fortuitous conditions they elude observation. Having established, however, a relationship in one area, the problem is before us to determine whether the river system of the larger area of Connecticut exhibits any indication of the existence of rectilinear directions more or less persistent embraced in a network of parallel series like that of the Pomperaug Valley; or, if this be not true, whether any other persistent and recurrent directions can be observed. It will be further of special interest if such a system affords indication of a regular space-interval between such parallel lines of drainage.

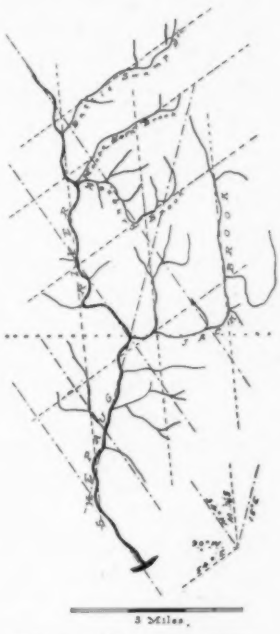

FIG. 2.— Diagram to show the relationship of drainage lines in the basin of the Shepaug River to the prevalent fault and joint lines of the neighboring Pomperaug basin.

The oriented drainage of the Shepaug River.— In prosecuting our inquiry regarding the orientation of the drainage lines of Connecticut, the valley of the Shepaug River (its southern portion) was first examined, since this basin immediately adjoins to the west that of the Pomperaug. The diagram of this river traced from the atlas sheet of the map of Connecticut, prepared by the topographic corps of the United States Geological Survey (Fig. 2), affords clear evidence that the geological structure planes have here played an important part in giving direction to the river's channels. The dotted lines of the figure show the inferred approximate positions of fault planes whose course the river has adopted. The most marked adhesion of the river or its

branches to any given direction is very closely the direction N. 5° W., as shown by the upper course (in the diagram) of the trunk stream, as well as by the upper course of Jack Brook, its main eastern tributary, and by the small intermediate branch of the latter. These three channels are not only evenly spaced, but to the southward their extensions correspond in position with the southerly trending elements of great elbows of the Housatonic (see Plate II). After receiving the waters of Jack Brook, the Shepaug flows for nearly three miles in the direction S. ± 15° W. (N. ± 15° E.), another of the four prevailing fault directions observed in the Pomperaug Valley. Later it flows S. ± 34° E. (N. ± 34° W), while several tributaries flow along this direction and S. ± 55° W. (N. ± 55° E.), the two remaining of the four prevalent fault directions of the Pomperaug Valley.

The oriented drainage within the area surrounding the Pomperaug Valley.— In the map of Plate II, a larger area, of which the Pomperaug Valley is the center, has been considered. Upon this map, traced from the United States Geological Survey atlas sheets, which are on a scale of one inch to the mile, the full straight lines represent observed faults (extended), and the dotted lines the inferred approximate position of faults. It has, of course, been necessary to omit all but a few of the numerous faults which were observed in the Pomperaug Valley area. The figures on the margin of the map indicate the directions (in degrees) either to the east or west of north of the trough or fault lines which emerge near them. With the greater complexity of this map and the larger number of fault directions represented, relationships are not at once so apparent as in Fig. 2, which upon a reduced scale is here included. Special attention is directed, however, to the fact that the Housatonic itself, which after flowing about three miles in a direction S. ± 5° E. (N. ± 5° W.), assumes the direction S. ± 61° E. (N. ± 61° W.) at first in a nearly straight channel for three miles, and then in a zigzag course for eight miles more. Many interesting peculiarities will be noticed in the orientation of the smaller streams shown upon this map; as, for example, along the N. ± 55° E.

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Plate II

RIVER MAP OF THE AREA SURROUNDING THE POMPERAUG VALLEY

The full lines are observed faults of the Pomperaug Valley area (extended); the dotted lines are "trough lines" (inferred approximate positions of joint or fault planes); the figures on the margin give the angle in degrees to the east or west of the meridian of the "trough lines" which pass near them.

line which approximates to a diagonal of the map, along the N. ± 33° E. line which meets the lower margin of the map near where the Housatonic meets it, etc. It will hardly escape notice, also, that the most marked lines in each series are spaced with considerable regularity, and if one space is wider than the others, it is often so much wider as to suggest that the space-interval is a multiple of the space which has been regarded temporarily as the unit.

The river system of Connecticut.—An examination of the larger area approximately coëxtensive with that of the state of Connecticut has been made by use of the "two-sheet map of Connecticut," on a scale of one half inch to the mile, prepared by the United States Geological Survey Those lines and characters of this map, such as topography and culture, with which we are not now concerned and which would obscure the relationships sought, were eliminated by preparing a careful tracing of all the streams and their minor branches. Upon this map tracing (about six feet long by four wide) approximately rectilinear stretches of river channel, and especially the stretches of neighboring streams which hold approximately to the same line, were sought. If these directions were found to agree closely with any of the fault directions observed in the Pomperaug basin, dotted lines were drawn following those directions and coinciding as closely as possible with the river courses. If such an observed direction was found not to coincide closely with any of the fault directions determined, a direction was sought which would approximate most closely to it, and a similar dotted line with this direction drawn along the course of the river. The term "trough lines" used to designate these lines, need for the present be given no further signification than lines so favored by nature that the waters of the region have been induced to adopt them for their channels over longer or shorter distances. On a map of this scale the trough lines, if rectilinear, should be slightly curved, but inasmuch as the present river courses, because of the many accidents of their history, can only roughly approximate to the direction initially given them, it would be an

over-refinement to introduce a correction of this nature, and they are, therefore, left straight. When all important trough lines had been thus represented, the map was reduced by photography and the etching of Plate I produced after the important rivers had been made a little heavier in order that their course might be apparent. These details of the study have been noted because the dangers of introducing the personal element while drawing the course of a river with any theory of its orientation in mind are very great. The map conveys a wrong impression, therefore, chiefly in its slightly exaggerating the volume of certain streams which it was necessary to draw with heavier lines in order that their correspondences might be apparent.

The first trough lines to impress the observer are those designated a_1, a_2, a_3, a_4, upon the map, lines which trend approximately N. 44° W., and which include the lower reaches of the Housatonic, of the Connecticut below Middletown, of the lower Willimantic and the Shetucket, and a stretch of the Quinebaug. A less-marked trough line between a_1 and a_2, would include important bends of the Naugatuck and Quinnipiac rivers. The sharp bend of the Connecticut River at Springfield and Patchoug River, tributary to the Quinebaug, may indicate the course of another trough line in this series. Most noteworthy of all lines in this series, however, is a_2, since the lower stretch of the Connecticut (some twenty-five miles long) is continued in the zigzag Sebethe River, so as almost to connect with the stretch of the Farmington River above its sharpest bend at Farmington. The direction of the lower stretch of the Connecticut is of especial interest because the river at Middletown deserts the softer Newark sediments to flow across the crystalline uplands, a peculiarity which has been explained by Professor Davis[1] through conformable superimposition, the stream being supposed powerful enough to maintain an initial course along this direction during the rise of the uplands, at which time the harder gneisses were discovered. The same hypothesis has been offered by Kümmel[2] to

[1] DAVIS: The Triassic Formation of Connecticut, Eighteenth Ann. Rep. U. S. Geol. Surv., Pt. II, 1898, p. 165.

[2] KÜMMEL: Some Rivers of Connecticut, JOUR. GEOL., Vol. I, p. 379, 1893.

explain the lower course of the Housatonic, which similarly deserts the limestone to cross the uplands. The presence of important structure planes in these positions would, in the view of the writer, afford the simpler explanation. It will be noted here that there is considerable uniformity in the spacing of the trough lines of this series, especially a_2, a_3, a_4.

The next most striking series of trough lines is indicated in the course of the Connecticut from Springfield to Hartford (c_1), a distance of twenty-six miles; of the Willimantic (c_2); of the Mt. Hope (c_{2a}); the Little (c_3); and a long stretch of the Quinebaug (c_4). The direction of these trough lines is about N. 5° E., though this is not one of those observed to characterize the faults in the Pomperaug Valley area. Again, the spacing of these trough lines is quite regular if we regard the space between the Connecticut and the Willimantic as a double interval. More striking, perhaps, than any of these trough lines is the one indicated in the series of smaller streams which extend along the line c_5 of the map. These streams are too small to deserve names upon a map of this scale, but some of them are known as Five-Mile River, Whetstone Brook, Moosup River, Mt. Misery Brook, etc. The direction of the series was in fact obtained from them and applied to the other trough lines in the series. This direction, while not an observed fault direction, corresponds to the longer diagonal of two unit orographic blocks of the Pomperaug Valley placed in contact along their shorter sides (see the dotted diagonal in Fig. 1), and thus it fills an important gap in the system of dislocations outlined.

The trough lines d_1, d_2, and d_3, which trend N. $\pm$ 15° E., represent a third series. The line d_1, which corresponds in position with no very important stream, is an observed fault of the Pomperaug Valley area (extended), in which area, however, the Pomperaug River adheres closely to its direction; d_2 corresponds closely for a distance of about fifteen miles with the course of the lower Naugatuck; while to the south the lower Housatonic flows in a nearly parallel direction some distance farther to the east. Most striking of this series is the trough

line d_3, along which are arranged stretches of the West, the Quinnipiac with its tributary the Ten-Mile, the Farmington with its tributary the Pequabuck (for about fifteen miles), and a minor branch of the Farmington, which enters at its last great bend. This line, except near New Haven, is some distance east of the curving western boundary of the Newark area of the Connecticut valley.

The only important fault line observed to hold to the direction of the N. $\pm$ 20° E. faults, which is marked f on the map, follows the Quinnipiac for about fifteen miles and continued northward coincides with the course of the Connecticut for a distance of about six miles.

Following the direction N. $\pm$ 33° E. are the trough lines e_1, e_2, e_3, e_4, e_5, and e_6, the latter less marked than the others, and e_4 being an important observed fault in the Pomperaug Valley area. The line e_2 follows for a distance of fifteen miles or more, the middle course of the Housatonic; e_3 is nearly in line with the Croton and the Aspetuck rivers; while e_5 is outlined by the Pine River and the small branch of the Connecticut, which is continuous with the southwesterly flowing elbow of that river at Middletown. The line e_6 shows no striking correspondences on a map of this scale, though midway between it and e_5 the Salmon River, a branch of the Connecticut, for about seven miles follows the direction closely.

The trough lines of the N. $\pm$ 5° W. series (b_1, b_2, b_3, etc.), while not prominently marked by the courses of any great streams, save for short distances by the Housatonic, the Naugatuck, and the Connecticut, yet all show on a larger scale map in the minor stream branches many interesting correspondences. As this direction agrees more or less closely with the slope of the Cretaceous plain of erosion of southern New England, the failure of the strong streams to follow this direction is worthy of note.

Though less marked than some of the other series, the trough lines which trend N. $\pm$ 90° E. W. seem to be clearly outlined, especially h_1, which passes through the divide of the

Farmington and Quinnipiac at Plainville, and h_2, which follows the easterly course of the Connecticut for a distance below Middletown.

A trough line seems to be indicated in the Salmon River and a branch of the Willimantic (g). This direction is N. 48° E. and does not correspond to any observed fault direction in the Pomperaug Valley area. Neither is it the diagonal of any very simple composite block of that area, which otherwise might indicate its relationship to this system.

Conclusions.—In conclusion it may be stated that the rivers of Connecticut seem to indicate by the orientation of their channels the existence of a regular network composed of a number of intersecting series of parallel lines, which for lack of a better term have been designated *trough lines;* and, further, that with two exceptions the more important of these trough lines correspond closely in direction with the directions of fault series observed to characterize the complexly faulted area of Newark rocks in the Pomperaug Valley. Of the two exceptions to the rule, the more noteworthy one (N. ± 5° E.) fills an important gap in the system of faults determined for that area. This study is therefore in its bearing a confirmation of the conclusions arrived at by Kjerulf, Daubrée, and Brögger, who have seen in the orientation of water courses the strong directing influence of geological structure planes.

There are obviously a number of ways in which the dislocations of a region, like the one under consideration, might be made to account for the orientation of stream courses. The direction of streams by the joint or fault planes themselves may be competent to explain the network indicated, more particularly if the streams began their cutting in the soft Newark sediments, which easily sustain secondary fractures near fault planes. That some voids occur along the fault planes of the Pomperaug Valley would seem to be indicated by the fact that these planes have conducted the underground waters to the surface at so many places within the area of the Newark rocks. Tension joints should, however, be more effective than compression joints in the control of drainage

lines, if it be assumed with Daubrée that the gaping fissure planes have directed the streams in their courses. The presumptive evidence is, the writer believes, in favor of the former development of the Newark rocks over a much larger territory than that which they now occupy and probably over the entire state of Connecticut.

It is an observation of much interest that the minor twig-like branches of the streams, which in the deeply eroded mass of crystallines must have been adjusted after the capping of sandstones had been removed, show an equally strong tendency with the master streams to follow the special directions indicated by the system as a whole.[1]

The study of the fault system of the Pomperaug Basin offers, however, another rational and natural explanation of the network of streams, provided the assumption is made that the drainage is adjusted to that formed in the geographic cycle which succeeded the deformation of the area. The system of parallel faults has divided the area into vertical triangular, rhombic, or rhomboidal prisms, which stand at different relative altitudes. These prisms are found to be grouped into composite blocks of increasingly higher orders, the peculiar property of each of which is that the average altitude of its component prisms approximates (however roughly) to a fixed value—the composite blocks have an average level surface, although alternate prisms or alternate subordinate blocks for short distances project above or stand below the general level. The initial surface formed by these prisms would be marked by canal-like structure trenches (*Graben*) which follow the directions of fault planes and which have stronger directive power, as regards streams, at the junction of the trenches and at the crossings with the similar trenches of other series.

Although the numerous generally curving fault planes discovered by Davis in his extensive studies of the Newark of the Connecticut valley have here been omitted from consideration, for the reason that no close relationship to the orientation of

[1] Twenty-first Ann. Rept. U. S. Geol. Surv., Pt. III, p. 145, Fig. 52.

streams is apparent in their directions, there is no intention thereby to minimize the importance of those studies. The investigation of the smaller Newark area of Connecticut, which by contrast was almost microscopic in its detail, brought out a series of facts which for their interpretation required a totally different theory from the one to which Professor Davis was led by his studies. The two hypotheses have, however, this in common, that the primary cause of the deformation in the Newark rocks is assumed to be the compression of the crust within the area of southern New England by a force of compression, the resultant of which acted in a direction W. N. W. to E. S. E.

The present writer has been led to the conclusion that the courses of large faults within this general area, if not approximately rectilinear, are in reality zigzags, the elements of which are essentially right lines, examples of this kind being by no means rare in, and, in fact, generally characteristic of, the Pomperaug Valley. It is not impossible that many of the larger faults described by Professor Davis, if examined in greater detail, might show this peculiarity, and perhaps also fall into the system which has here and elsewhere been elaborated. The numerous broken lines which are so apparent in the boundaries of the trap hills of the Connecticut valley, as represented on the topographic atlas sheets (*e. g.*, Meriden sheet), would seem to favor this view. It is in any case important, as it would seem to the writer, to consider in two stages the dislocations brought about mainly by a lateral compression of a section of the earth's crust, inasmuch as jointing (the production of planes of separation) is in these cases a necessary prerequisite to faulting (displacement along planes of separation). The modern views of geologists concerning joint planes produced by the shear from lateral compressive stresses are now sufficiently in accord to assume that vertical block faulting takes place along ready-formed planes of jointing. In his description of the faulted area of southern Norway, Brögger[1] has been careful to make this distinction.

[1] Loc. cit.

With the explanation of the numerous diversions of rivers from their rectilinear stretches this paper is not especially concerned, although some explanation of such diversions could be found in the peculiarities of a region faulted like that of the Pomperaug Valley. The modern criteria of the physiographer deal adequately with this matter. It is the definite orientation of water courses which the new science seems to have neglected.

WILLIAM HERBERT HOBBS.

COMPOSITE GENESIS OF THE ARKANSAS VALLEY THROUGH THE OZARK HIGHLANDS

On account of its singular course through the Ozark highland region the Arkansas River presents, at the present time, unusual geological interest. Its location in this part of its course, has given rise to two very different opinions regarding the geological age of the highlands; and also regarding the question as to whether there are two distinct uplifts, as has been advocated by the Arkansas geologists, or only one, as has been urged by others who have worked in the region. Recently there have accumulated new data bearing directly upon the problem.

Topographically, the Ozark highlands comprise two imposing, nearly equal, elevated regions, separated from each other by a broad deep trough—the Arkansas River valley. The vast plain surrounding the highlands is about 400 feet above sea level on the eastern side and twice this elevation on the west side. The Arkansas River flows along on the horizon of this general grade-plain. On the south side of the river the highlands rise to heights of nearly 3000 feet above the sea; and on the north to about 1800 feet.

Diverse apparently in topographic expression, lithologic composition, geologic structure, and geological age, the district south of the Arkansas River has been known as the Ouachita Mountains, and that north of the stream the Ozark plateau. On the assumption that there are two distinct uplifts, the river of Arkansas is regarded as forming a natural dividing line between the two regions. At first glance, the simplest explanation for the position of the stream is forced upon the attention. Premising a single uplift, the accounting for the waterway's course meets with difficulties which, from superficial consideration, appear well-nigh unsurmountable. The present note attempts to sum up the evidence going to show that the facts actually sustain the second premise.

In comparing the two districts, it is their differences and not their points of resemblance which are most conspicuous. In the Ouachita region the surface relief is notably mountainous, long ridges and isolated peaks, with wide, flat-bottomed valleys intervening. In the northern district the country is far from appearing mountainous; it is, for the most part, a vast undulating plain, but sharply and deeply dissected around the borders, with the streams flowing in V-shaped valleys. In the south the rocks are more or less indurated or metamorphosed, and cut at intervals by eruptives. Nowhere in the north do the strata

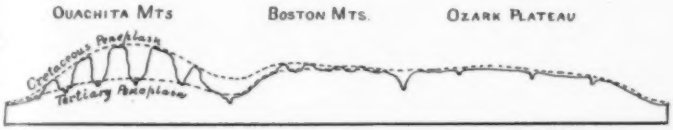

FIG. 1.— Peneplains of the Ozark region.

show alteration or evidence of the presence of eruptives. The southern district is folded to a marked degree, approaching closely the Appalachian structure; while the northern region is only gently bowed. Regarding the geological ages of the two districts, the Ouachita has been thought to have been upraised towards the close of the Carboniferous; the northern area has been commonly considered as having been an elevated region ever since pre-Cambrian times. The present uplift, however, is now believed to be of very recent origin; and the upward movement is thought to be still in progress.

The physiographical history of the region and the relations of the graded surfaces of the Ozark highlands are best indicated in diagram (Fig. 1).

Two distinct base levels are discernible in the region. They have been called the Cretaceous and the Tertiary peneplains. These titles will be retained for the present. The first of the peneplains rises out of the level savannas of the Mississippi embayment, but soon becomes deeply broken as it rises and passes into the Ouachita region. It is there believed to be

continued northward in the mountain summits, which are often flat-topped.[1] The later peneplain is thought to be represented in the intermontane flats which are about 1500 feet lower than tops of the mountains. The floor of the Arkansas valley is coincident with the Tertiary peneplain. Beyond the stream northward the Tertiary surface rises rapidly according to Hershey,[2] and soon in the region of the Boston Mountains the two peneplains practically merge. In Missouri only the Tertiary plain has been distinguished, and this is regarded as forming the general upland surface of the uplift.

It is probable that north of the Boston Mountains it will be exceedingly difficult to differentiate at any point the two peneplains. Present evidence goes to show that during the interval between the formation of the two peneplains in the south the erosion in the north was comparatively slight, and resulted in merely lowering the general surface of the plain already formed during the Cretaceous.

Some time ago it was incidentally stated that the Ozark highlands formed a single unit bowed up from the Red River to the Missouri.[3] The most obvious support for this conclusion is found in the physiographic development of the region. But the evidence is not alone from this source.

The physiographic data would indicate that in the Ozark region the uprising since Cretaceous times has been not only periodical in its character, but that it has been also differential. Lately the movement has been more marked in the north than in the south.

But there were special conditions existing that enabled the Arkansas River to hold its own against the great barrier which started to rise across its course. In a limited belt in this part of the Ozark region an enormous mass of non-resistant clay shales had been deposited in Carboniferous times. The thickness attained was much greater than that of the Carboniferous

[1] Arkansas Geol. Surv., Ann. Rept., 1890, Vol. III.

[2] American Geologist, Vol. XXVII, p. 25, 1901.

[3] Missouri Geol. Surv., Vol. VIII, p. 331, 1895.

sediments anywhere else on the American continent, being upward of 20,000 feet, according to Branner.[1] The peculiarities of this great sequence of soft shales have lately been discussed in some detail, and the real significance of the Arkansan series, as it is called, pointed out.[2]

Thus, independent of whatever geological structure the Arkansas valley may have, the enormous column of shales was of such character as to enable the great stream to scoop out a trough sufficiently vast and broad to give its topographic form

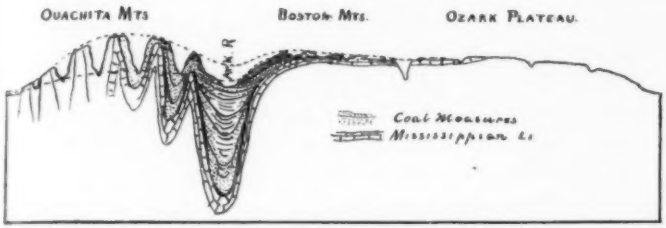

FIG. 2.— Stratigraphy of the Ozark Highlands.

the effect of a depression between two uplifts.

There is another deceptive feature connected with the valley of the Arkansas, that must be taken into consideration. Besides being a topographical trough, the valley is also a structural trough. A broad and shallow syncline stretches from the crest of the Boston Mountains to the first range of the Ouachitas. The strata closely folded in the extreme southern part of the highland district spread out rapidly towards the north until they form gentle undulations that are so characteristic of other parts of the Mississippi basin. The Ozark arch in Missouri constitutes the last great swell northward. Its southern limb passes into the broad syncline which contains the Arkansas valley. This relationship of structure is represented by a north and south cross section (Fig. 2).

The operation of different geological processes may be either

[1] Am. Jour. Sci., (4), Vol. II, p. 235, 1896.

[2] Bull. Geol. Soc. America, Vol. XII, p. 173, 1901.

all compensating, or all cumulative in their effects. Between the two extremes the sum of the antagonistic tendencies may have very variable values. The present valley of the Arkansas River as it crosses the Ozark highlands is a noteworthy illustration in which the combined effects of perfectly independent processes are curiously cumulative in character. It is on this account chiefly that the real facts concerning the development of the great uplift have been so largely obscured.

Summing up: The different geological conditions when the Arkansas River initiated its course across the Ozark region, (1) an undeformed lowland flat in which the strata had been folded to a marked degree before being beveled and the country reduced to the state of a peneplain, (2) a remarkable, yet narrow, belt, bordered on either side by resistant rocks, of soft shales of prodigious thickness which, when a new epoch of uprising was inaugurated, enabled the stream to easily keep its channel down to the general base level of the country surrounding the uplift, and (3) a broad structural trough, which, however, was only one of many synclines nearby and parallel to it—were highly cumulative in effect in imparting to the uplift the present aspect of twin elevations. By this singular combination of geological conditions the Arkansas River instead of being forced to turn aside by the great topographic dome which, out of the Cretaceous peneplain, arose athwart its path, was able to saw in two the arching strata.

Topographically, the Ozark highlands form two distinct elevated regions. Structurally as well as topographically the Arkansas valley is a trough. But structurally the Ozark highlands, as a whole, form an immense dome bowed from the Red River to the Missouri.

CHARLES R. KEYES.

A SECOND CONTRIBUTION TO THE NATURAL HISTORY OF MARL[1]

THE writer recently published a paper on the relation of algae to marl deposits.[2] Since it appeared, continued investigation has led to the discovery of additional confirmatory evidence that the close relationship there pointed out of the algae, especially Chara, to marl or lake lime deposits, exists to even a greater extent than was suspected.

Experimental work has been conducted along three lines, all of which have been fairly productive of results, and a brief account of this work may be of interest.

First, a series of mechanical analyses of typical white marl from different localities were made. The method of analysis used was a simple one, a modification of the beaker method used in soil analysis. The sample, chosen at random from a large specimen from the deposit under investigation, was dried in an air bath at 110° C. for sufficient time to remove any included moisture, and weighed. It was then mixed with distilled water in a large beaker and thoroughly stirred with a rubber-tipped glass rod, care being taken to stir it until all lumps caused by the adhesion of the finer particles to the coarser were broken up Care was also taken that no more crushing should take place than was absolutely necessary. After all lumps were disintegrated, the water, with the finer particles suspended in it, was poured off into another beaker and fresh water was added to the first and the material was again stirred. This was continued until water poured into the first beaker was nearly free from finer matter and became clear on standing a few moments. The coarse material left in the bottom of the beaker was dried, sorted into various grades by a series of sieves and each grade weighed.

[1] Printed by permission of ALFRED C. LANE, State Geologist of Michigan.

[2] JOUR. GEOL., Vol. VIII, No. 6. September–October 1900.

The finer material was also sorted by stirring, settling, and decantation, and the matter of different degrees of fineness dried and weighed. The finest matter was usually separated from the water by filtering through a dried and weighed filter, and the water concentrated by evaporation and again filtered to remove any of the calcium carbonate dissolved in the various processes, and the final residue of water was evaporated in a watch glass and weighed. An exceedingly interesting feature of this latter experiment was the finding of a water soluble calcium salt, in small proportion, it is true, but still easily weighable and not to be neglected. The results of such an analysis of a sample from the Cedar Lake marl beds in Montcalm county, Mich., gave the following results. The sample used was collected from a hole made with a spade by cutting away the turf over the marl, then taking out sufficient marl to be sure that there was no peat or other surface matter present and the material used taken from a spadeful thrown out from two or three feet below this level. From this sample about thirty grams were taken and treated as described above, and after the finer material had been separated from the coarser by washing and drying, the latter was passed through a set of standard gauge sieves, twenty, forty, sixty, eighty, and one hundred meshes to the linear inch, after which all shells and recognizable shell fragments, sand grains and vegetable débris, up to the sixty-mesh siftings, were removed and weighed separately. This gave the following grades: (1) Material too coarse to pass through the twenty-mesh sieve, (2) that held by the forty-mesh, (3) that held by the sixty-mesh, (4) that held by the eighty-mesh, (5) that held by the hundred-mesh, (6) that which passed through the hundred-mesh, (7) that which was filtered out, (8) water soluble salts, (9) shells, shell fragments, and miscellaneous matter.

The following is the result of the analysis of Cedar Lade marl made and graded as described:

Grade (1)		32.25 %
	(2)	6.06
	(3)	7.58
	(4)	2.90
	(5)	4.81
	(6)	15.64
	(7) }	30 52 [1]
	(8) }	
	(9)	0.28
		100.04

A second analysis was made from a specimen made up of twenty samples taken by boring with an auger over about one-half of the deposit at Littlefield Lake, Isabella county, most of the samples coming from a depth of at least twenty feet, six to eight meters below the surface of the deposit. This analysis gave the following results:

Grade (1)		31.52 %
	(2)	14.48
	(3)	12.76
	(4)	2.56
	(5)	6.74
	(6) }	30.42
	(7) }	
	(8)	0.27 [2]
	(9)	1.04
		99.79

A third sample, from the holdings of the Michigan Portland Cement Company at Coldwater, Mich., a fine high grade white marl, very powdery, gave the following: Weight of sample, 20.— grams.

Grade (1)		0.36 %
	(2)	3.53
	(3)	6.51
	(4)	3.34
	(5)	6.44
	(6)	28.99
	(7)	49.12
	(8) Not determined.	
	(9)	0.69
	Loss and soluble matter (by difference)	1.02
		100.00

[1] In this case determined by drying down the residue and weighing.

[2] The soluble matter contains a certain undetermined amount of alkaline chlorides as well as a soluble calcium salt.

These samples represent (1) central, (2) north central, and (3) southern parts of the lower peninsula respectively, and may be taken as typical of the marl deposits of Michigan. When it is stated that, in general, it is easily possible to recognize with a simple microscope the particles which are held by the one hundred-mesh sieve, or even those which pass through it, if the finer matter has been carefully separated by washing, as characteristic Chara incrustation or Schizothrix concretions, it will be seen that these results show conclusively that a large part of the marl from these three samples is identifiable as of algal origin, and studies of the marls from other localities give similar results.

The Coldwater sample (3) was exceedingly fine in texture, and it was difficult to avoid loss in sorting and weighing, as every current of air carried away some of the particles, and some also adhered to sieves and weighing dishes in spite of all precautions. Even this sample shows nearly 50 per cent. of easily identified Chara incrustation. The fineness of the particles in a given marl bed varies much in different parts of the bed, and the degree of fineness is probably chiefly dependent upon the conditions of current and wave action under which the bed was formed, that which was deposited where the wave or current action was strong being coarser than that in stiller water or that on the lee side of exposed banks. This fact was noted at Littlefield Lake when samples of marl were collected along exposed shores above the wave line, which were 95 per cent. coarse fragments of Chara incrustation and Schizothrix nodules, while in other parts of the shore line the marl was of such fineness that it was like fine, white clay. The fragments of the Chara incrustation are generally easily recognized even when of minute size, because they preserve, usually very perfectly, the peculiar form of the stem and branches of the plant. This structure of the stem and branches is, in brief, a series of small tubes, grouped about a larger central one, and is easily seen with the unaided eye in larger fragments. Even when the tubes have been crushed, as is the case with many of the thinner ones,

it is frequently possible to recognize fragments of them with the compound microscope. Finally the incrustation is distinctly crystalline in ultimate form of the constituent particles, and when it has disintegrated the crystals and their fragments are found to constitute a large per cent. of the finer particles of the resulting marl. On the growing tips of the younger branches and the leaves of Chara, numbers of isolated crystals of calcium carbonate may be seen. Farther back on stems and branches the crystals become more numerous, then coalesce into a thin, fragile covering, and finally on the lower part of the plant the covering becomes dense and thick. It is evident therefore that the decay of the younger parts of the plants would furnish a mass of more or less free or loosely aggregated crystals of microscopic size, which would retain their crystalline form, in some degree at least, for an indefinite time and be recognizable, hence the presence of microcrystals in marl may furnish additional evidence as to the origin of the deposits.

The larger fragments of Chara incrustation as found in marl are frequently much thicker and heavier than any which occur among fragments of recent origin, *i. e.*, those obtained from any part of living, vigorously growing Chara from the beds of the plant existing in ponds from which the marl may have been obtained. While this subject needs further investigation, it is probable that such thickened incrustations have originated in several ways, the principal ones being, if the writer's notes have any bearing on the subject, as follows:

1. On short, stunted plants that grow for a long time on unfavorable soil, such as sand or pure marl. Such plants have relatively very short internodes and generally thick incrustations, much thicker than those on plants growing normally.

2. From the growth of the lime-secreting, blue-green algae, such as Schizothrix, Rivularia, etc., either upon living chara or upon the fragments of broken incrustation, as a nucleus. Such a growth might produce considerable thickening of the Chara incrustation.

3. From the inclusion of the fragments within the nodules

formed by the growth of the incrusting blue-green algae, in shallow water, and the subsequent destruction of the nodules by wave or other disintegrating action. In this case a thickened fragment may be left either free or attached to other material. Several fragments may be cemented together, and such aggregations have been observed.

4. By the deposition of calcium carbonate on fragments of incrustation, the source of the salt deposited being soluble calcium-organic compounds left free in the water by the decay of dead Chara, the precipitation being caused by the reducing action of chemical compounds derived from the decay of organic matter or the growth of bacteria. It may be conceived also that the calcium carbonate thus deposited might also act as a cementing material to fasten the finer particles of marl to the incrustation as a nucleus.

5. By the deposition in more or less coarsely crystalline form of calcium carbonate which is dissolved by water percolating through the marl. This is probably considerable in amount and takes place in a manner analogous to, if not identical with, the formation of concretions in clays and shales. It is probable that in this way the crystals may be formed, which rather rarely are found filling the cavities in the Chara incrustations, left by the large axial cells of the plant. The fact that in the great majority of cases these cell cavities are entirely empty or are simply mechanically filled with fine particles of marl, is a most serious objection to considering that this form of chemical precipitation is an important one in the history of marl, but that it is occasionally operative is extremely probable.

6. It is possible that the thick incrustations may have been formed at some earlier period in the history of the lakes when conditions for the development of the plant forms and their activities were greater. This is not probable however, for the thick incrustations are often found from the surface of the marl beds throughout the entire deposits.

In addition to the marl analyses given above a check analysis was made of a specimen of material made up from the washings

and fragments of a mass of Chara plants collected from Cedar Lake, and allowed to die slowly and to break up in water kept cold and fresh by conducting a small stream from the hydrant through it. The plants gradually died, broke up, and settled to the bottom of the containing vessel and seemed to undergo farther disintegration there from the growth of fungi, eventually forming a relatively finely divided deposit which was of rather dark color, when wet. A quantity of this was dried at 100°C., some of the longer and larger fragments of stems were removed, and the residue was weighed and subjected to the same treatment as the marl samples. The analysis gave the following:

Grade (1)	1.12%
(2)	24.43
(3)	14.63
(4)	8.26
(5)	7.81
(6) and (7)	33.83
(8)	0.39
(9)	0.12
Soluble organic matter and loss	9.41
	100.00

It will be seen that nearly as much fine matter was present in this material as in the finest of the marls analyzed, and that the finer grades of sifted material are quite as well represented as in the finer marl. The material is somewhat more bulky for a given weight and is perhaps slightly darker in color, but not much more so than many samples of marl.

Grade for grade it is identical in appearance and structure to the marl samples, and the only possible difference that can be detected is the slightly green tint and the organic matter present in the plant residue. It is also noticeable that the larger pieces do not show as thick an incrustation as do the larger pieces from the marl samples and, of course, Schizothrix and other coarse matter is not present.

It will be seen by inspecting the analyses, that shells and recognizable shell fragments are but a very insignificant part of

the total quantity of the marl. It is surprisingly small when all things are taken into account. While it is probably true that not all the minute shell fragments have been separated in any of these analyses, it is also true that the weight of such overlooked particles is more than counterbalanced by marl fragments which are included within the cavities of the whole shells, and adhere to both broken and whole shells in crevices and sculpturings in such a way as to refuse to become separated in the processes of washing out the marl. The whole shells are mainly small, fragile forms, many of them immature, and it is evident that they would be broken by any action that would crush the Chara incrustation.

A second line of investigation took into consideration the milky appearance of the waters of some marl lakes. This has been considered by some investigators as possibly due to the presence of calcium carbonate precipitated from the water either by the liberation of dissolved carbon dioxid from the water and hence from the calcium bicarbonate or by change of temperature of the water after it has reached the lakes.

The writer has not found among the marl lakes of the southern peninsula of Michigan that those with turbid water were common, even where marl banks were apparently forming with considerable rapidity.

"Merl" or Marl Lake in Montcalm county, situated on the same stream as Cedar Lake and a mile or more below it, is, however, one of the lakes in which the water is usually of almost milky whiteness, and has sufficient suspended matter in it to render it nearly opaque for depths of a meter or a little more. The conditions in this lake are widely different from those at Cedar Lake and other marl lakes in the vicinity and are suggestive of the cause of the turbidity. At Cedar Lake there is a border of grassy or sedgy marsh extending around the lake on three sides and generally underlaid by marl, and the lake bottom slopes sharply and abruptly from the edge of the marsh to a depth of at least ten meters. In other words the lake is simply a deep hole, with steep sides, and perhaps represents the

deepest part of the more extensive lake which formerly occupied the area included by the marsh and marl beds. This marsh covering is general on the marl beds of the region and the lake may be said to be a typical marl lake for the locality in which it lies, for there are several others near by which are practically identical in essential points of structure.

At Marl Lake, however, the filling of the lake has not reached the same stage. There is practically no open marsh, but the lake is shallow for seventy-five or a hundred meters from the shore, then abruptly deepens to an undetermined depth over a relatively small area. The bottom over the shallow area is of pure white marl, and the water is apparently not more than sixty or seventy centimeters deep at the margin of the central hole, while near the shore it is scarcely one-third as deep. In brief, here is a lake in which there is a broad platform of marl surrounding a deep hole, which again is all that remains of the deep water of a lake which is filling with marl. Boring shows that the bed of the lake is nearly as far below the surface under the marl platform, as where the marl has not yet been deposited.

Upon the shoreward edges of the platform and in small areas farther out upon it, the turf-forming plants are beginning to establish themselves, but as yet they have not made any marked impression, seeming to have a hard struggle to get a foothold. The conditions are then a broad area of shallow water overlying a wide platform of marl, which, if a strong wind should reach it, would be stirred to its depths, and with it the lighter parts of the marl upon which it rests. The marl thus stirred up, in turn, is carried to all parts of the lake by surface and other currents and makes the water turbid. These facts led to an investigation as to the rapidity with which marl, once stirred up, would settle out of perfectly still water, and some interesting results were obtained. The experiments were made as follows: (1) A glass tube 1.58 meters long and 2.5 centimeters wide was filled with distilled water, into which a quantity of finely divided marl was turned and the tube was shaken to insure a thorough mixing of water and marl. The tube was then

clamped into a vertical position and left perfectly still until the marl had settled out, notes being made, daily at first, of the rate of settling. In the beginning, the heavier particles settled rapidly, forming, as does clay in settling from water with which it is mixed, stratification planes, which, however, after a few days disappeared, and only the lighter parts of the marl remained in suspension. These were distinctly visible for five weeks, on looking through the tube towards a window, and at the end of six weeks, a black object lowered into the tube in a well-lighted room, was not visible beyond ninety centimeters from the surface of the water. (2) A glass cylinder with a foot, 38^{cm} high and 7^{cm} wide, having a capacity of a little more than a liter was nearly filled with distilled water and the residue from the washings of a sample used in analysis was thoroughly mixed with it, and set aside, notes being made as before. This material subsided rather more slowly than the other, and at the end of ten weeks, under daylight illumination, the bottom of the vessel was barely visible when one looked down through the water from above.

The results obtained by Barus[1] in his work on the subsidence of solid matter into suspension, in liquids, show that settling is much more rapid in water containing dissolved salts, even small proportion, than in distilled water, and the foregoing experiments were checked as follows: (1) A cylinder about the size of the one used in the second experiment was filled with water in which a small amount of calcium chlorid had been dissolved, and ammonium carbonate was added until a precipitate was formed. This was stirred thoroughly and left to settle. In three days the precipitate had fully subsided and the liquid was clear. (2) Two cylinders of equal size were filled, one with distilled water, the other with water from a river fed, in part, by marl lakes. Equal quantities of fine marl were shaken up with the water and the rate of settling was compared. The marl was not as fine as that used in the other studies and settled more rapidly. The river water was clear in fifteen days, while the

[1] CARL BARUS: "Subsidence of Fine Solid Particles in Liquids." Bull. of the U. S. Geol. Surv., No. 36.

distilled water was not clear when the experiment terminated, but was nearly so, showing that the subsidence was not quite so rapid in distilled water as in natural lake or river water.

These results indicate that, if for any cause the marl in a marl lake is stirred up effectually, as it may be in those where the beds are exposed to wave action, the water will remain turbid for some time; even in summer time the chances are that there will be sufficiently frequent high winds to keep the water always turbid. It may be stated that in some of the lakes which have been studied by the writer, the marl beds have filled the entire lake to within a fraction of a meter of the surface of the water, with some parts only a few centimeters deep. Until such shallows are occupied by vegetation the water is likely to be turbid from the mechanical action of waves upon the deposits. At Littlefield Lake, described elsewhere,[1] the water is only slightly turbid, although there are extensive shallows and exposed banks, but there the body of water is extensive and of considerable depth, while the greater part of the exposed marl is granular and the particles too coarse to be held long in suspension, and the finer deposits too small and too well protected to be reached by effective waves, so that the amount of suspended marl is not great enough to produce marked turbidity in the entire body of water.

It may be worthy of note that the residue of suspended matter, filtered out from the sample of Chara fragments (analysis (4) above) was sufficiently fine to give a marked turbidity to distilled water for several days, and at the time of filtering had not subsided, demonstrating the fact that very finely divided particles may originate from the simple breaking up of the Chara plants by ordinary decomposition of the vegetable matter.

It is difficult to account for the fact that the deeper parts of marl lakes are generally free from any thick deposits of a calcareous nature. Lack of records of sufficient exploration makes any statement purely tentative, but about seven to nine meters[2]

[1] C. A. DAVIS: "A Remarkable Marl Lake," JOUR. GEOL., Vol. VIII, No. 6.

[2] WESENBERG-LUND: Lake-Lime, Pea Ore, Lake Gytje. Saertryk af Meddelelser fra Dansk Geologisk Forening, No. 7, p. 156.

seems to be the limit of depth of recorded occurrence of Chara plants. The remains of the plants, then, would only accumulate, in place, above that depth, and the material reaching greater depths would be that held in suspension in the water, and hence be relatively very small in quantity and accumulate slowly. A possible additional cause of slow accumulation is that in the greater depths, *i. e.*, over ten meters, the greater abundance of dissolved carbon dioxid held in solution by pressure dissolves the finer particles of marl which reach these depths.

From these investigations it seems (1) that marl, even of the very white pulverulent type, is really made up of a mixture of coarser and finer matter covered up and concealed by the finer particles, which act as the binding material. (2) That the coarser material is present in the proportion of from 50 to 95 per cent. (3) That this coarser material is easily recognizable with the unaided eye and hand lens, as the incrustation produced on the algae, Schizothrix and Chara, principally the latter, to particles less than one one-hundredth of an inch in diameter. (4) That the finer matter is largely recognizable under the compound microscope as crystalline in structure, and is derived from the algal incrustation by the breaking up, through decay of the plants, of the thinner and more fragile parts, or by disintegration of the younger parts not fully covered. (5) That some of this finer matter is capable of remaining suspended in water a sufficiently long time, after being shaken up with it, to make it unnecessary to advance any other hypothesis to explain the turbidity of the waters of some marl lakes, than that it is caused by mechanical stirring up the marl by wave or other agency. (6) That shells and shell remains are not important factors in the production of the marl beds which are of largest extent. (7) That there is in marl a small amount of a water soluble calcium salt, readily soluble in distilled water, after complete evaporation.

[a] A. J. PIETERS: Plants of Lake St. Clair, Bull. Mich. Fish Commission, No. 2, p. 6.

Studies were undertaken to determine the method of concentration and precipitation of the calcium carbonate by Chara.

As has already been indicated elsewhere, the calcium carbonate is present on the outside of the plant as an incrustation, and this is made up of crystals, which are rather remote and scattered on the growing parts of the plants, and form a complete covering on the older parts, which is uniformly thicker on the basal joints of the stems than it is on the upper ones. Considering the hypothesis that the deposition of the salt was the result of purely external chemical action as not fully capable of satisfying all the existing conditions, the formation of the incrustation was taken up as a biological problem, and an investigation was made upon the cell contents of Chara, first, microscopically by the study of thin sections. Various parts of the plant were sectioned while still living, and the attempt was made to find out if the calcium carbonate was present as a part of the cell contents in recognizable crystalline form. Various parts of the plant were examined, but no crystals undoubtedly in place among the contents of the cells were observed, although numbers were to be seen on outside walls of all cells.

Next an attempt was made to determine the presence of the calcium in soluble form in the cell contents, by the use of dilute neutral solution of ammonium oxalate. An immediate response to the test was received by the formation of large numbers of minute, characteristic, octahedral crystals of calcium oxalate on the surface and imbedded in the contracted protoplasmic contents of the cell. The number of these crystals was so large, and they were so evenly distributed through the cell contents, that it was evident that a large amount of some soluble calcium salt was diffused through the cell sap of the plant. The next step was to isolate this compound and to determine its composition. A considerable quantity of the growing tips of Chara were rubbed up in a mortar and the pulp was thoroughly extracted with distilled water. This water extract was filtered and tested to determine the presence of calcium and an abundant precipitate obtained by using ammonium oxalate,

which, on being separated and tested, proved to be calcium oxalate. It was evident that the calcium salt in the plant was stable and readily soluble in water. This latter fact was farther demonstrated by evaporating some of the extract to dryness and again taking it up with water. Almost the entire amount of the calcium salt was redissolved, only a small portion of it becoming insoluble and precipitating as the carbonate. This ready solubility demonstrated the fact that the salt was not derived from the incrustation on portions of the plant used, and the same fact excluded from the list of possible compounds, salts of some of the mere common organic acids found in plant juices, which are insoluble.

Qualitative chemical tests were, however, made to determine, if possible, whether any of these acids were present with negative results, and it was demonstrated by this means that there was but a single salt present and not a mixture. Search was then made to determine the acid present, and a result obtained which was so unexpected that it was seriously questioned and the work was gone over again. The second result confirmed the the first and the work of ascertaining the correctness of these two results was turned over to Mr. F. E. West, Instructor in Chemistry in Alma College, who had had special training and much practice in organic analysis. His work was done entirely independently, with material gathered at a different season, and by another method of analysis, but his results were identical with my own, and show that calcium exists in the water extract of Chara as calcium succinate. The fact that the succinate is one of the few water soluble calcium salts and that there is a soluble salt of the metal in the cell sap of the plant makes it probable that this is the compound of the metal which the plant accumulates in its cells.

It is not possible from actual investigation to explain the method by which the calcium salt is abstracted from the water, where it exists as the acid- or bi-carbonate or the sulphate[1] in

[1] It has been shown that Chara decomposes several calcium salts, the sulphate among others.

small per cent., and is concentrated in the cells of the plant as calcium succinate and later deposited upon the outside of the same cells as the normal or monocarbonate in crystalline form in considerable quantities.

Some culture experiments which were undertaken by the writer to determine under what conditions of soil, light, and temperature Chara thrives best, incidentally demonstrated that the plant actually gets its lime from the water and not from the soil. One of the soils which was used as a substratum in which to grow plants was pure quartz sea-sand which had been washed with acid to remove any traces of calcium salt which might be present. The plants grew in this medium readily, and on the newer parts developed nearly, if not quite, as many calcium carbonate crystals as plants growing in pure marl. It should be apparent, however, to even the casual observer that the plants cannot take all the lime they precipitate from the soil, or even a considerable part of it, for if they did the marl beds, being made up principally of Chara remains, would never have accumulated, for the material would have been used over and over again and could not increase much in amount, if it increased at all. In the present state of our knowledge of the life processes of aquatic plants, it seems hardly possible to state the probable method of the formation of the calcium succinate, or even the probable use of it to the plant, and no attempt will be made by the writer in the present paper to do so. It does seem probable, however, that this compound accumulates in the cells, until it reaches sufficient density to begin to diffuse through the cell walls by osmosis. Outside the cells, or in its passage through the walls, it is decomposed directly into the carbonate, possibly by oxidation of the succinic acid by free oxygen given off by the plants, possibly by some substance in the cell walls, or, more probably, by the decomposition of the acid by some of the organic compounds in the water, such as the organic ferments, due to bacterial growth in the organic débris at the bottom of the mass of growing Chara. The water extract of Chara rapidly changes on standing, undergoing putrefactive

decomposition, becomes exceedingly offensive in odors developed, and calcium carbonate crystallizes out on the bottom and sides of the containing vessel, while the succinic acid disappears, gas, possibly carbon dioxid, being given off more or less abundantly. Whether these changes takes place on the outside of the living plants, in the cell walls, or in the water surrounding the plants has not yet been determined.

Sufficient evidence is here presented, however, if the writer's conclusions are correct, to show that the plants under discussion are active agents in the concentration of calcium salts in the fresh water lakes of Michigan, and that they alone have produced a very large part of the marl which has accumulated in these lakes. It seems probable also that the principles developed by these studies are of very wide application in working out problems presented by formations developed under similar conditions elsewhere.

CHARLES A. DAVIS.

ALMA COLLEGE,
July 1, 1901.

PERKNITE (LIME-MAGNESIA ROCKS)[1]

THERE are sometimes associated with diorites, gabbros and peridotites, dark rocks composed largely, or entirely, of monoclinic amphibole or pyroxene, or both. These rocks differ mineralogically from diorites and gabbros, in containing little or no feldspar, and from peridotites in containing rhombic pyroxine or olivine in relatively small amount, if present at all. Chemically these rocks contain less alumina than diorites and gabbros, and less magnesia than peridotites. They are low in alumina and in the alkalis, moderately rich in lime, magnesia, and the iron oxides.

The chief constituents of perknite are monoclinic amphibole and monoclinic pyroxene; the secondary constituents rhombic pyroxene, olivine and feldspar; the accessories biotite, iron ore, etc., but only one of the primary constituents may be present with none of the secondary constituents or accessories. The existence of this group of rocks has long been recognized, but from their occurrence usually in small masses, and from the fact that many of them are of simple composition so that the self-explanatory names pyroxenite and amphibolite or hornblendite have answered, they have never been grouped together under one name.

In the State of New York[2] and in California[3] there are rocks containing both monoclinic pyroxene and amphibole as principal constituents, and doubtless this is likewise the case in many other parts of the world. Moreover, in California such rocks form areas of geological importance. There is, therefore, some reason in grouping all of these lime-magnesia rocks under a common name. It is proposed to call the group *perknite* from

[1] Published by permission of the Director of the U. S. Geological Survey.

[2] G. H. WILLIAMS: Am. Jour. Sci., Vol. XXXI, 1886, p. 40.

[3] TURNER: Am. Jour. Sci., Vol. V, 1898, p. 423. Turner and Ransome. Sonora folio.

the Greek word *περκνος*, meaning dark. It will include granolites of the following specific names:

Pyroxenite.

Hornblendite (Williams).

Websterite (Diallage and ortho-rhombic pyroxene) (Williams).

Diallagite.

Hornblende-hypersthene rock (Merrill).

Amphibole-pyroxene rock (Turner).

The group may be graphically represented by the method employed by Hobbs[1] and his representation of a composite pyroxenite will approximate to that of a typical perknite. The following table of analyses will give the reader a notion of the composition of the rocks which may be properly included in this group.

1. *Hornblendite.*—Geo. Steiger, analyst. This partial analysis is here published for the first time. The rock is from a dike cutting through the basement complex and overlying Cambrian rocks, 2 km north of Silver Peak village, in Esmeralda county, Nev. It is composed chiefly of green hornblende with some feldspar. The rock grades into a basic diorite.

2. *Amphibole-pyroxene rock.*—W. F. Hillebrand, analyst. Not before published. Rocks of this type are very abundant in Mariposa county, Cal. Mr. F. M. Anderson, of the University of California, has likewise collected them in northern California. This rock in its typical development is composed of original pyroxene and amphibole in grains of nearly equal size, with a little quartz and pyrrhotite. Scattered through the rock are phenocrysts about one centimeter in diameter, of brown amphibole, which contain in a poikilitic manner, as inclusions, the constituents of the groundmass.

3. *Perknite* (author's name, *peridotite*).—Belchertown. Bull. U. S. Geol. Survey, No. 168, p. 30. L. G. Eakins, analyst. The rock is composed of hornblende, pyroxene, biotite, olivine and magnetite.

[1] Jour. Geol., Vol. VIII, 1900, p. 14.

ANALYSES OF PERKNITES; LIME-MAGNESIA ROCKS.

Name	I Hornblendite	II Amphibole-pyroxene rock	III Perknite	IV Pyroxonite	V Websterite	VI Websterite	VII Composite pyroxonite
SiO_2	46.28	48.04	48.63	50.80	53.25	53.21	52.58
Al_2O_3	.....	7.82	5.32	3.40	2.80	1.94	3.69
Fe_2O_3	.....	2.01	2.91	1.39	.69	1.44	1.90
FeO	.....	9.32[1]	3.90	8.11	5.93	7.92	6.50
MgO	19.54	13.33	21.79	22.77	19.91	20.78	20.86
CaO	9.91	13.01	13.04	12.31	16.22	13.12	13.23
Na_2O	2.21	.69	.34	trace	.19	.11	.22
K_2O	1.89	.48	.23		trace	.07	.10
$H_2O-110°C$	.....	.17	2.81	.52	.05	.14	.57
$H_2O+110°C$	.....	2.90			.24	.87	
TiO_2	.....	1.16	.47	none	.....	.26	.11
ZrO_2	.....	.....	.....	.....	.....	trace	....
CO_2	.....	none	trace	.....	.....	.10	....
P_2O_5	.....	trace	.21	trace	.....	trace	....
SO_3	.....	.23[2]	.....	trace	.....	.....	....
S	.....	.90	.....	Cl. .24	.....	FeS_2 .03	....
V_2O_3	.....	.....	.....	.....	.....	.03	....
Cr_2O_3	.....	.90	.36	.32	.54	.20	....
NiO	.....	.....	.....	.....	.07	NiO + CoO .03	....
MnO	.....	none	.12	.17	.09	.22	.11
BaO	.....	none	trace	.....	.....	none	other constituents
SrO	.....	.....	.....	.....	.....	none	.50
Li_2O	.....	.....	.....	.....	.....	trace	....
Total	.....	100.06	100.13	100.03	99.98	100.47	100.49
Less O	.....	.45					
		99.61					

4. *Pyroxenite.*—Johnnycake road, Baltimore. Bull. U. S. Geol. Survey, No. 168, p. 42. Composed entirely of hypersthene and diallage.

5. *Websterite.*—From Mt. Diablo. W. H. Melville, analyst. Bull U. S. Geol. Survey, No. 168, p. 213, and Bull. Geol. Soc. Am., Vol. II, p. 406; analysis No. 242. The rock is composed of orthorhombic pyroxene and diallage.

[1] Owing to analytical reasons this determination of ferrous iron is unsatisfactory.—W. F. Hillebrand.

[2] This determination somewhat doubtful.—W. F. H.

6. *Websterite.*—Oakwood, Cecil county, Md. Composed of hypersthene and diallage. W. F. Hillebrand, analyst. Bull. U. S. Geol. Survey, No. 168, p. 43.

7. *Composite pyroxenite.*—Hobbs, JOUR. GEOL., Vol. VIII, p. 30. This analysis is a composite from three analyses of pyroxenites, and one analysis of a hornblende-hypersthene rock from Gallatin county, Mont.

Professor J. S. Diller, in his bulletin on "The Educational Series of Rock Specimens,"[1] introduces three specimens which would fall into the perknite group.

No. 110, a pyroxenite, is described by Professor George H. Williams.

No. 111, feldspathic peridotite, is described by Professor George H. Williams.

No. 113, Cortlandite (hornblende-peridotite), is described by Williams and Iddings. The rock is composed of brown hornblende, olivine, pyroxene, biotite, feldspar, and magnetite.

Some rocks that have been termed wehrlite will fall also into this group.

EFFUSIVE AND DIKE ROCKS

Corresponding to the plutonic group of perknite there undoubtedly occur effusive and dike rocks. Professor Rosenbusch regards hornblende-picrites as effusive, and some of these have the chemical and mineral composition of perknite. This will also be true of augitites, since in these augite or monoclinic pyroxene is the chief constituent.

Professor J. P. Iddings has been kind enough to criticise the above paper and calls my attention to the fact that my definition of perknite would bring into the group the kimberlite of Kentucky with 9.46 per cent. of lime, and the kimberlite of South Africa with 9.60 per cent. of lime, as wellas the amphibole-peridotite of Schriesheim with 7.22 per cent. of lime. He also calls attention to the fact that with hypersthene-enstatite rocks there

[1] Bull. U. S. Geol. Surv., No. 168.

may be very little lime present and yet they would not be peridotite. This brings us to the re-definition of peridotite, and I should define a peridotite chemically as a magnesia rock with usually less than 6 per cent. of lime. This would put a rock composed entirely of hypersthene or enstatite with the peridotites, where they certainly belong chemically.

H. W. TURNER.

SAN FRANCISCO, CAL.,
June 20, 1901.

THE BORDER-LINE BETWEEN PALEOZOIC AND MESOZOIC IN WESTERN AMERICA

THERE have been in recent years in America many controversies as to the Silurian-Devonian and the Devonian-Carboniferous boundaries; but American geologists have always felt secure as to the line of demarcation between the Paleozoic and the Mesozoic. This has always been thought to be marked by a grand chasm, a hiatus in stratigraphy and a break in life, accompanying a great change in physical geography, all of which is true of the region east of the Rocky Mountains.

But later discoveries in the Great Basin region have shown that the gap is at least partly filled out by marine sediments, and that the hiatus is not universal in America. The most important of these discoveries was the finding of marine Permian in northern Texas, with forms suggestive of the Mesozoic types of life, and the finding in southeastern Idaho of marine Lower Trias, with a fauna reminiscent of the Paleozoic.

Recently there has been evident among geologists a tendency to revert to first conditions in determining the boundaries of geologic systems. They have been inclined to use unconformities as the dividing lines between geologic groups, and to look upon geologic systems as realities, and not mere names for the convenience of stratigraphers. This must mean that they regard the geologic events that delimited the systems as of world-wide effectiveness, or even of cosmic origin. But almost every trangression of the sea has been found to be balanced by a retreat elsewhere, every uplift to have its correlative subsidence. And in still other parts of the earth there may have been neither uplift nor subsidence. Even the Appalachian revolution did not effect the western Carboniferous Sea, and this is generally admitted to have been one of the greatest events in the dynamic history of North America.

In defining the upper Paleozoic and the lower Mesozoic no

account was taken of conditions of formation, and this has led to endless difficulties in correlation. The Upper Carboniferous was based entirely on lacustrine deposits, and the identification of its marine equivalent is still making trouble for geologists. The Permian was based on a basin deposit, partly lacustrine and partly of brackish water origin, and the recognition of its purely marine types has caused much controversy in Europe and America. The Trias was based at first entirely on the deposits of the Germanic inland sea, and only recently has any uniformity been attained in its correlation and nomenclature.

The greater divisions are now all named, and there is no room for new systems, all geologic time, and possibly something over, being taken up by those already defined. But because the first naming of geologic divisions was based on unconformities, which represented erosion intervals and consequent gaps in the record, further exploration must necessarily bring to light somewhere in the world passage beds between the artificial systems. What rules then shall be followed in the correlation of these passage-beds, or new formations? If the new formations are shown to be the homotaxial equivalents of parts of systems already defined, there can be no question, for faunal or lithologic differences cannot be taken in account in different provinces or regions.

If the new formation, however, lies between two systems, one of which is sharply defined and the other described only vaguely, as including the beds below or above the one with definite boundaries, then the passage-beds must naturally be assigned to the system with a flexible margin.

If both the bordering systems should be definitely bounded, or if neither should be, then one or the other must be stretched to take in the passage-beds, and the assignment will be based on paleontologic relationship to one or the other. But if this relationship should be no closer to one than the other, then priority of assignment would have to decide on the nomenclature of the doubtful beds.

The geologists of India have for many years recognized that

in the Himalayas and the Salt Range there was a continuity of life and sedimentation from the Paleozoic into the Mesozoic, and there the line of demarcation has been arbitrary. The stages or zones used in drawing this paleontologic line in India have become types, and are used in interregional correlation wherever similar beds are known. A section is given below of the uppermost Permian and the Lower Trias of India, for convenience of comparison with the American section.

SECTION OF THE PERMIAN AND LOWER TRIAS OF INDIA AFTER WAAGEN, DIENER, AND NOETLING

- **Trias**
  - Middle — Upper Ceratite limestone.
  - Lower
    - Ceratite sandstone
      - Flemingites beds.
      - Stachella beds.
    - Otoceras beds
      - Ceratite marls.
      - Lower Ceratite limestone.
- **Permian**
  - Upper
    - Upper Productus limestone, with *Cyclolobus oldhami*, and *Xenaspis carbonaria*.
    - Middle Productus limestone, with *Xenaspis carbonaria*.
  - Lower
    - Lower Productus limestone, with *Fusulina kattaensis*.
    - Glacial beds.

Waagen drew the line between Paleozoic and Mesozoic at the base of the Ceratite formation because of a supposed unconformity, and because the Permian types of brachiopods such as *Productus*, *Chonetes*, and the Orthidae have not been found above this line. But the unconformity has since been shown not to exist, and several of the Permian ammonite genera range up into the Ceratite formation, such as *Otoceras*, *Medlicottia* and *Xenaspis*.

The upper Productus limestone is acknowledged to be younger than any known European marine Permian, and the *Otoceras* beds are universally considered to be older than any Trias yet known from Europe; therefore the continuity of sedimentation and life makes it exceedingly difficult to draw a line that will satisfy everybody. And, indeed, if either the Trias or the Permian had been named first in India, there would have been no division of this series.

The Wichita Permian of Texas, while carrying forms such as *Medlicottia*, *Waagenoceras*, and *Popanoceras*, harbingers of the varied Triassic ammonites of later times, contains in its other members so many Paleozoic types that no one would think of

classing it in the Mesozoic. There can be no controversy as to its age, which is approximately equivalent to that of the lower Productus limestone of India. It lies conformably on the Coal-measures, and contains many species that have ranged up from the latter.

But above the Wichita Permian lies the great series of the Red Beds. These have been assigned sometimes to the Permian and sometimes to the Trias, and they, doubtless, belong to both. Marine fossils have been found in these Red Beds only in three places. The Geological Survey of Texas [1] found in the Double Mountain formation at the falls of Salt Croton Creek, Kent county, Texas, *Medlicottia*, *Waagenoceras*, and *Pleurophorus*, all akin to forms from the Wichita beds. The writer has examined these forms and recognizes them to be still typically Permian in character, although they are very near the top of the formation. Above these beds lies the fresh water "Dockum" series referred by Cope to the Trias.

C. N. Gould [2] has recently found marine and brackish-water Permian fossils in the Red Beds of Oklahoma, in the Cimmaron series; the forms still being of Paleozoic type, such as *Conocardium*, *Aviculopecten*, *Schizodus*, *Pleurophorus*, and *Bakevellia*. The stratigraphic position of these is equivalent to the Double Mountain beds of Texas, and they belong unequivocally to the Paleozoic.

In the Red Beds of Utah, at Ft. Douglas near Salt Lake City, F. Frech [3] has found *Pleurophorus imbricatus* Waagen, *Allorisma* conf. *elegans* King, *Emondia aspinwallensis* Meek, *Schizodus schlotheimi* King, and *Dalmanella* sp. indet., a fauna that would pass for Paleozoic anywhere, and belongs in the same horizon as the Double Mountain beds of Texas and the Cimmaron series of Oklahoma and Kansas. They are the homotaxial equivalents of the Upper Permian.

[1] Geological Survey of Texas, Second Annual Report, 1890. Report on the Geology of Northwestern Texas, by W. F. CUMMINS, p. 408.

[2] JOUR. GEOL., Vol. IX, 1901. No. 4, p. 337.

[3] Lethaea Geognostica, Vol. II, Lieferung 3. 1900, p. 515.

From the close of the Coal-measures the land encroached on the basin-sea by a progressive westward uplift, and the brackish water and basin deposits take a successively higher place in the geologic column towards the west. Thus somewhere in the eastern part of the Great Basin region marine intercalations of Lower Trias may be expected to be found in the Red Beds. Indeed, this formation in southeastern Idaho lies above and conformably upon the marine limestones with a Lower Triassic fauna. It is, then, in the upper part of this Red Beds formation, in the fresh and brackish-water deposits and its rare marine facies, that we are to seek for the transition from Paleozoic to Mesozoic.

C. A. White[1] has described from the Aspen Mountains of Idaho a marine fauna older than any Trias known up to that time in America, and younger than any known Permian. The Meekoceras beds in which this fauna was found he assigned to the Lower Trias. According to A. C. Peale[2] this formation lies conformably upon the Carboniferous, and below the Red Beds. The *Meekoceras* fauna was found near the base of the series, which here has a thickness approximating three thousand feet. The Carboniferous limestone below contained *Productus multistriatus* Meek, which has been found by the writer in the uppermost Paleozoic beds of California, and has been cited as a characteristic fossil of the Permian of northern Europe.

Since that time Professor Alpheus Hyatt and the writer have visited the Meekoceras beds, and their joint collections yielded; *Meekoceras gracilitatis* White, *M.* (*Gyronites*) *aplanatum* White, *M.* (*Koninckites*) *mushbachanum* White, *Aspidites*, *Flemingites*, *Pseudosageceras*, *Ussuria*, *Ophiceras*, *Clypites*, *Danubites*, *Nannites*, and a number of new genera.

The writer[3] has previously described the Ceratite limestone of the Lower Trias of Inyo county, California. During the past

[1] Twelfth Ann. Rep. U. S. Geol. and Geog. Surv. Terr., Part I (1880). Triassic Fossils from Southeastern Idaho.

[2] Bull. U. S. Geol. and Geog. Surv. Terr., Vol. V., No. 1 (1879). Jura-Trias Section of Southeastern Idaho and Western Wyoming, p. 119.

[3] Jour. Geol., Vol. VI, No. 8, 1898. Geographic Relations of the Trias of California.

winter he has visited this locality and added a great many species and genera to the collection from that formation. Those now known from there are: *Meekoceras gracilitatis* White, *M.* (*Gyronites*) *aplanatum* White, *M.* (*Koninckites*) *mushbachanum* White, *M.* conf. *radiosum* Waagen, *M.* conf. *falcatum* Waagen, *M.* aff. *boreale* Diener, *Aspidites*, *Prionolobus*, *Danubites*, *Proptychites*, *Xenaspis*, *Lecanites*, *Nannites*, *Ussuria*, *Pseudosageceras*, and *Clypites*, besides a number of new genera. Several of the species, both new and described, are identical with forms from the *Meekoceras* beds of southeastern Idaho, with no greater difference in the fauna than might be expected in localities separated by six hundred miles.

Below the *Meekoceras* beds of Inyo county lie several hundred feet of barren shales, and below these is siliceous limestone containing *Fusulina*. Above the *Meekoceras* beds are eight hundred feet of calcareous shales with impressions of ammonites, and then a few feet of black limestone with *Acrochordiceras*, *Hungarites*, *Tirolites*, *Ceratites*, and *Xenodiscus*, and *Parapopanoceras*, probably belonging to the base of the Middle Trias. The entire series appears to be conformable, from the Upper Carboniferous to the Middle Trias.

The fauna of the *Meekoceras* beds of Idaho and California is most intimately related to that of the Ceratite formation of India, and of the homotaxial *Proptychites* beds of Ussuri in eastern Siberia. *Meekoceras*, *Gyronites*, *Koninckites*, *Danubites*, *Proptychites*, and *Ophiceras* are known both in the Ceratite formation of India, and in the Ussuri beds of Siberia; *Pseudosageceras* and *Ussuria* are known elsewhere only in the Ussuri formation; and the species of all these regions are nearly related, in part apparently identical.

It is, therefore, plain that the correlation of the Ceratite formation of India has a direct bearing on the determination of the age of the Meekoceras beds of America. Albert Oppel, who in 1865 described fossils from the Ceratite formation of India, referred them at first to the Jura, and then afterwards to the Trias, as typical Jurassic beds were found considerably above

them. But before this, in 1863, de Koninck, who also described a number of ammonites from the Ceratite formation, referred them very doubtfully to the Paleozoic, because they were supposed to have come from the Productus limestone. C. L. Griesbach[1] who first described the fauna of the *Otoceras* beds of India, referred them to the Lower Trias, in which he has been followed by Wilhelm Waagen[2] and Carl Diener.[3] These writers consider the lower part of the Ceratite formation to be younger than any known Permian, and older than any fauna described from the European Trias, but they regard the affinities of the species as closer to known Mesozoic types, and the beds were considered as homotaxial with the lower part of the Werfen sandstone, the base of the Trias in the Mediterranean region. Now since this part of the Mediterranean section is barren of fossils, this correlation is based entirely on the stratigraphic position of the Ceratite formation.

C. Diener[4], in describing the fauna of the *Proptychites* beds of Ussuri Bay in eastern Siberia, correlated them with the *Otoceras* beds of India, because of the occurrence of several species common to the two regions. It is, therefore, evident that while the correlation of the Ceratite formation of India with the *Proptychites* beds of Siberia and the *Meekoceras* beds of western America may be accepted as correct, the final determination of the age of these beds depends entirely on a comparison with the type of the Lower Trias, the Buntsandstone of Germany, and the Werfen beds of the Alps.

In spite of the weakness of this argument, the Ceratite formation of India has until recently gone unquestioned as the type of the strictly marine equivalent of the Lower Trias, and all

[1] Records Geol. Surv. of India, Vol. XIII, 1880. Paleontological Notes on the Lower Trias of the Himalayas, p. 94.

[2] Mem. Geol. Surv. India, Pal. Indica, Ser. XIII. Salt Range Fossils, Vol. II. Fossils from the Ceratite Formation.

[3] *Ibid.*, Ser. XV. Himalayan Fossils, Vol. II, Part I. Cephalopoda of the Lower Trias.

[4] Mem. Com. Geol. St. Petersbourg, Vol. XIV, No. 3. Triadische Cephalopodenfaunen der Ostsiberischen Küstenprovinz.

correlations of the marine beds have been made by comparison with it. During the last year F. Noetling,[1] paleontologist of the Geological Survey of India, has startled geologists in their fancied security, by the statement, based on his later investigations, that the *Otoceras* beds of India belong to the upper Permian, and are older than the Werfen beds of the Alps. As they lie conformably upon the upper Productus limestone, they represent, according to Noetling, strata of which the equivalents are lacking in the European section. Accordingly he proposes to call the entire Ceratite formation upper Permian, and as a name for the stage he proposes the term Bactrian. If this should prove to be correct it would throw the Ceratite formation of India, the *Proptychites* beds of Siberia, and the *Meekoceras* beds of Idaho and California into the upper Permian.

A. von Kraft,[2] also of the Geological Survey of India, agrees with Noetling, but only as to the Permian age of the *Otoceras* beds; the upper part of the series where *Meekoceras* and *Flemingites* are so abundant he regards as certainly of lower Triassic age. He says that *Medlicottia dalailamae* Diener of the *Otoceras* beds is identical with *M. wynnei* Waagen of the upper Productus limestone, and that *Cyclolobus oldhami* Waagen and *Xenaspis carbonaria* Waagen, which in the Salt Range occur in the middle Productus limestone, in the Himalayas occur in the Kuling Productus shales only twenty or thirty feet below the *Otoceras* beds. This would make the bottom of the *Otoceras* beds (the lower Ceratite limestone) the equivalent of the upper Productus limestone of the Permian. This argument, however, might work both ways, for it would just as well prove that the upper Productus limestone belonged to the base of the Trias, since in any case the division line must be arbitrary. Nor would the finding of *Productus* itself in the *Otoceras* beds prove them to be

[1] Geol. Surv. of India, General Rept. for 1899 (1900). Notes on the Relationship between the Productus Limestone and the Ceratite Formation of the Salt Range, and Neues Jahrbuch für Min. Geol. und Pal., 1900. Bd. I, p. 139, Ueber die Auffindung von Otoceras sp. in der Salt Range.

[2] Centralblatt für Min. Geol. und Pal. Bd. II, 1901, p. 275, Ueber das Permische Alter der Otoceras-Stufe des Himalyas.

Paleozoic, for if *Otoceras*, *Medlicottia*, *Xenodiscus*, and *Xenaspis* can range into the Mesozoic, there is no known reason why *Productus* should not have done so. Indeed, *Xenaspis* and *Xenodiscus* range up into the Middle Trias, associated with faunas characteristic of the Muschelkalk.

C. Diener[1] meets Noetling's argument by stating that if the Ceratite formation of India is not of Lower Triassic age, then we have nowhere in the world a strictly marine equivalent of the Werfen beds, and that we have the anomaly of Middle Triassic beds lying conformably on Permian. He shows that the marine Permian of the Alps, which lies below the Werfen beds, has not the fauna of the *Otoceras* beds, but one analogous to that of the *Productus* limestone. Diener admits that the *Otoceras* horizon is older than the fossilferous portion of the Werfen beds, but thinks that the rule of priority of reference must be followed, where there are no paleontologic grounds against it and many for it. He also cites a recent paper by A. Bittner[2] to show that there is found in the *Proptychites* beds of Ussuri a typical pelecypod and brachiopod fauna of Werfen character; it must be admitted, however, that this fauna was not found with the ammonites, and might belong considerably above them.

The most direct comparison with the European Trias has been made by Lukas Waagen,[3] who shows that in the Ceratite marls and the Ceratite sandstone of India he has identified a number of pelecypods identical with forms characteristic of middle and upper Werfen beds of the Alps. This leaves the question about as A. von Kraft stated it. The Ceratite formation, from the Ceratite marls up, certainly belongs to the Lower Trias, since the Werfen beds are the type, while the *Otoceras* beds of the Himalayas, or their equivalent, the lower Ceratite limestone, may belong to the upper Permian. But the fauna of

[1] Centralblatt für Min. Geol. und Pal. Bd. I, 1900, p. 1, "Ueber die Grenze des Perm- und Triassystems, etc."

[2] Mém. Com. Geol. St. Petersbourg, Vol. VII, 1899, "Verstein. aus den Trias-Ablagerungen des Süd-Ussuri Gebietes in der Ostsibirischen Küstenprovinz.

[3] Centralblatt für Min. Geol. und Pal. Bd. I, 1900, p. 285.

the lower Ceratite limestone and that of the Ceratite marls are so similar that a separation of the two is out of the question, and even the genus *Otoceras* is found in the latter. Now, since these doubtful beds are younger than any accepted Permian, and older than any authentic Trias, they might with equal propriety be assigned to either, and we shall have to extend one or the other system to include them. The question will have to be decided either by paleontologic relationship, or by priority of reference. The *Otoceras* beds contain *Meekoceras*, *Proptychites*, *Ophiceras*, and several other ammonite genera that have never been found in the Paleozoic; they contain also *Medlicottia* and *Otoceras* that are more characteristic of Upper Permian; but they lack the Productidae and Orthidae that characterize the Permian formation. Thus the paleontologic evidence is about equal in favor of a reference to either Paleozoic or Mesozoic. But the geologists that described the fauna of the doubtful beds have almost unanimously referred them to the Lower Trias, and this must be the final verdict.

The fauna of the *Meekoceras* beds of Idaho and California is most intimately related to that of the Ceratite marls and the lower part of the Ceratite sandstone of India, with most of the genera in common, and several species that seem to be identical. And although the writer has searched carefully for *Otoceras* in both places, no trace either of this genus or of *Medlicottia* was found. It seems likely, then, that even if the bottom of the Ceratite formation should be cut off from the Trias and assigned to the Permian, this change would not affect the nomenclature of our American formations that are now considered as the bottom of the Mesozoic series, and the *Meekoceras* beds will stand as the type of the marine Lower Trias, where White and Hyatt placed them in 1879. The real transition from Paleozoic to Mesozoic must be sought in the conformable series below the *Meekoceras* beds, and above the *Fusulina* limestone.

JAMES PERRIN SMITH.

STANFORD UNIVERSITY,
California.

STUDIES FOR STUDENTS

THE CONSTITUENTS OF METEORITES. II

Glass.—This is an abundant constituent of the stone meteorites, few if any being entirely without it. It is variously distributed, occurring now as vein matter, now scattered through the substance of chondri, now enclosed in the substance of a single mineral, and now enclosing various minerals.

In the Parnallee, Mezo-Madaras, Chassigny, Farmington and a few other meteorites it has been described as forming a network in which the other minerals are imbedded. Its ocurrence in this manner is rare, however, it playing usually a merely accessory part. It chiefly abounds as inclusions and intergrowths in chrysolite, taking in this association a great variety of forms. Other minerals too, frequently have inclusions of glass. It may occur in fragments of considerable size or the particles may be of a dustlike minuteness.

Its abundance in chondri has already been mentioned. By all these occurrences a rapid crystallization or cooling of the meteorite substance is strongly indicated. Like the glass of terrestrial lavas it seems to be the result of cooling so rapid as to prevent differentiation and orderly crystallization of the magma. The especial abundance of glass in meteoritic chrysolite, the least fusible and therefore the earliest cooling ingredient further favors this conclusion.

The prevailing color of the glass of meteorites is brown. Much is however colorless and some occurs so dark as to be opaque. Grayish and greenish tones occur but are rare.

Chromite.—Nearly all stone meteorites give on analysis a small percentage of chromium which is usually considered as being present in the form of chromite, FeO,Cr_2O_3. The mineral is not so abundant in the iron and iron-stone meteorites

but has been detected in several and in the Coahuila irons occurs in nodules of considerable size ($17^{mm} \times 12^{mm}$).

It is identical with terrestrial chromite in composition and properties. Not being acted upon by acids, it may be readily distinguished from daubréelite. It is generally non-magnetic, but sometimes feebly magnetic. Where crystals occur they are commonly octahedrons, sometimes modified by other forms.

Amorphous carbon.—Meteorites of the group known as carbonaceous meteorites, as well as some others, are permeated by a dull-black pulverulent coloring matter which is usually left as a residue on treatment of the meteorite with acid. This residue sometimes amounts to from 2–4.5 per cent. of the mass.

A residue similar in character though smaller in amount is likewise found after dissolving many of the iron meteorites. These residues on being heated in air glow, usually become lighter in color and give off carbon dioxide. They must therefore be considered practically pure carbon.

Berzelius and Wöhler believed this carbon to have originated so far as the carbonaceous meteorites are concerned, from the decomposition of the hydrocarbons of the latter. In this respect they regarded it analogous to terrestrial humus, though of very different origin. Smith considered it similar in origin to the graphite of iron meteorites and Weinschenk believes it similar to one of the forms of carbon produced in the making of cast iron. No indications that it had an organic origin have ever been discovered.

Diamond.—The existence of diamonds has been definitely proven in only two meteorites, those of Cañon Diablo and Nowo-Urei. Diamonds have, however, also been reported from the irons of Magura and Smithville and the stone of Carcote. The diamonds of the Cañon Diablo meteorites have been most studied. Here they are found as minute particles or dust left as a residue after dissolving the meteorite in acid. The particles rarely exceed $\frac{1}{2}^{mm}$ in diameter. They are usually brown to black in color but sometimes are colorless and transparent. They accompany graphite, amorphous carbon and often troilite

and schreibersite. They have a tendency to gather in little clefts or hollows and are not regularly distributed. Their character as diamond is proven chiefly by their hardness, but analyses and a study of their behavior in polarized light give confirmatory results. Huntington found some also which showed crystal forms of diamonds. The occurrence of diamonds in meteorites suggests interesting analogies with their terrestrial occurrence. Knop and Daubrée call attention to the fact that the peridotic rocks in which terrestrial diamonds occur are the rocks most nearly allied in composition to meteorites. In the iron meteorites, as Moissan has proven satisfactorily by experiment, diamond is to be considered a form in which, under certain conditions of heat and pressure, carbon separates. Moissan obtained diamonds by heating to a high temperature iron saturated with carbon and allowing it to cool under pressure. The carbon was then found to exist in three forms, graphite, foliated carbon, and a diamond powder which latter corresponded to that obtained from the Cañon Diablo meteorites.

A form of carbon resembling graphite but differing in having a hardness of 2.5 and being isometric in crystallization, has been noted in the Magura, Cosby's Creek, Youndegin, Toluca and a few other iron meteorites. It was first discovered by Fletcher, who considered it a distinct species and gave it the name cliftonite. Other authorities, however, regard cliftonite as a pseudomorph after diamond, since its crystals closely resemble those of diamond in form.

Daubréelite.—This mineral is an iron-chromium sulphide peculiar to meteorites. Its composition is Fe S, $Cr_2 S_3$. It is found in nearly all the cubic iron meteorites and has also been identified in the irons of Toluca, Nelson county, Cranbourne, Cañon Diablo and others. It has never been found in stone meteorites. It usually accompanies troilite, either bordering nodules or crossing them in veins. Sometimes, however, it occurs as thin plates or grains. It is black in color, has a black streak, is of metallic luster, brittle and not magnetic. It is infusible before the blowpipe and becomes magnetic in the reducing flame. It is not

attacked by hot or cold hydrochloric acid, but is completely dissolved by nitric acid without the separation of free sulphur. This solubility distinguishes it from chromite. Its system of crystallization is not known though it exhibits rectangular and triangular partings which indicate one of the systems of high symmetry. Meunier obtained the mineral artificially by treating an alloy of iron and chromium at a red heat with hydrogen sulphide.

Tridymite.—This mineral has been positively identified in only one meteorite (Steinbach), but it probably also occurs in the Vaca Muerta and Crab Orchard Mountains meteorites. These are all ironstone meteorites. In the Steinbach meteorite it forms from 8.5 to 33 per cent. of the non-metallic constituents and occurs intergrown with bronzite.

Maskelyne, who first described the mineral, considered it on account of its optically biaxial character a new orthorhombic form of silica and gave it the name of asmanite. Since tridymite is now known, however, to exhibit biaxial characters and the minerals agree in most other respects, they are generally considered identical.

Tridymite occurs in meteorites in the form of rounded grains or plates, some of which reach a length of 3 mm. They are colorless to white to rusty brown in color.

Well developed crystals are rare but from facets on rounded grains a total of twelve forms has been determined.

Analyses show a composition of practically pure silica, with iron oxide and magnesia present as impurities.

Lawrencite.—This is a solid ferrous chloride which has been described from the iron meteorites of Tazewell, Smith Mountain, and Laurens county. Formula $FeCl_2$. Color green to brown. While described in the solid form from only the few meteorites mentioned, the presence of lawrencite in many other iron meteorites is generally believed to be indicated by the greenish drops which exude on their surfaces. These drops are ferric chloride or mixtures of ferric and nickel chloride, while occasionally pure nickel chloride occurs.

The meteorites from which ferric chloride exudes disintegrate with especial rapidity. Such meteorites are often known as "sweating" meteorites. The "sweating" is rarely noted in ironstone or stone meteorites, but the small percentage of chlorine found in the analysis of many of these meteorites is usually referred to lawrencite. Some authorities hold that the substance is not an original constituent of any meteorite, but is wholly of terrestrial origin. This is not the general opinion however.

Ferrous chloride has been noted among the sublimation products at Vesuvius and is reported as having been found in the terrestrial nickel-iron of Ovifak.

Magnetite.— Several stone or ironstone meteorites have been found to contain black, magnetic grains which dissolve in hydrochloric acid without effervescence to form a yellow solution.

In the meteorites of Shergotty and Doña Inez these are sufficiently abundant to form an essential constituent. They constitute 4.57 per cent. of the Shergotty meteorite. Similar grains occur as inclusions in maskelynite, pyroxene, and chrysolite in the above and other meteorites. They are regarded as magnetite.

No well marked crystals of meteoritic magnetite have as yet been described.

Magnetite has been reported as a constituent of several iron meteorites though only one analysis has been made, that of Meunier of magnetite from the crust of one of the Toluca irons. The composition of this agreed with that of terrestrial magnetite. Several other iron meteorites show magnetite in their crust. Here, however, the magnetite may have originated from the oxidation of the iron of the mass since its arrival upon the earth.

Magnetic spherules have been dredged up from ocean depths, which Murray and Renard regard as particles of meteoric iron oxidized to magnetite since their arrival upon the earth.

Oldhamite.—This is a simple calcium sulphide with the formula $Ca S_2$. Grains of it were found by Maskelyne embedded in the enstatite or augite of the Bustee meteorite. It is light

brown in color and transparent when pure. Hardness 4, specific gravity 2.58. It is isotropic and has equal cleavage in three directions, hence is doubtless isometric. In the Bustee meteorite it occurs in rounded grains, coated with gypsum through alteration.

Certain yellow grains found in the Bishopville meteorite were also considered by Maskelyne to be this mineral. Aside from these two occurrences it has not been positively identified in any other meteorite.

Calcium sulphide resembling oldhamite was obtained by Maskelyne by heating caustic lime in a glass tube, first with hydrogen, then with hydrogen sulphide. Vogt has noted a similar compound formed in furnace slags.

It has not been found as a terrestrial mineral.

On dissolving the oldhamite of the Bustee meteorite, Maskelyne found a residue constituting about 0.3 per cent. of the weight of the former, consisting of yellow octahedrons of microscopic size. These were found to be unaffected by acids or oxygen, while qualitative tests indicated sulphur, calcium, and titanium or zirconium. Maskelyne regarded the mineral therefore an oxysulphide of calcium and titanium and gave it the name osbornite. No other occurrence of the mineral is known.

Hydrocarbons.—The hydrocarbons found in meteorites may be divided, following Cohen,[1] into three classes: (*a*) compounds of carbon and hydrogen; (*b*) compounds of carbon, hydrogen and sulphur; and (*c*) compounds of carbon, hydrogen and oxygen. They especially characterize meteorites of the class known as carbonaceous, which includes seven or eight distinct falls of meteorites of black color, low specific gravity and containing a sensible amount of carbon. They have been obtained from some other meteorites however, such as those of Collescipoli and Goalpara. The hydrocarbons of the first class are obtained by treating these meteorites with alcohol or ether. They are resinous or waxlike bodies which completely volatilize on the application of heat. When heated in a closed tube the resinous substances first fuse,

[1] Meteoritenkunde. Heft. I, p. 159.

then are decomposed to form amorphous carbon and an oil hav- a bituminous or fatty odor. Such substances were considered by Wöhler similar to the mineral wax ozocerite and by Shepard they were designated meteoritic petroleum. Friedheim states that a substance extracted by him from the meteorite of Nagaya by means of ether had a bituminous odor, volatilized at 200° and resembled a product of distillation of brown coal. A similar substance extracted by Roscoe from the meteorite of Alais was found to have a composition corresponding nearly to the formula CH_{2n}.

Hydrocarbons of the second class were obtained by Smith by treating the graphite of iron meteorites and some carbonaceous meteorites with ether. These compounds were fusible and volatile. He regarded them as having the general composition $C_4H_{12}S_5$. He obtained similar products by treating cast iron with ether or petroleum as did also Berthelot by the action of ether on sulphur or iron sulphide in the presence of oxygen.

Hydrocarbons of the third class have been obtained from the meteorites of Orgueil and Hessle. The Orgueil extract resembles peat, humus or lignite in its composition and properties. That from Hessle has approximately the composition $n\,C_9H_8O_2$.

The above mentioned facts make it clear that a number of meteorites contain products of an easily destructible, volatile, and combustible character which resemble terrestrial bitumens, petroleum or oxygenated hydrocarbons. The quantity of these products is relatively small, being less than 1 per cent. in the majority of meteorites in which they occur. Yet that they occur at all is significant. While some have urged that these products might have arisen from the union of their elements in the terrestrial atmosphere there seems little reason for doubting their pre-terrestrial origin. There is no evidence that life had anything to do with their origin. We must conclude then that they were formed in an inorganic way by a union of their elements. The conclusion at once suggests the possibility that

terrestrial hydrocarbons need not always be referred to an organic origin, but may have been formed in a purely inorganic way.

The occurrence of hydrocarbons in meteorites further shows that such meteorites could not have been subjected to any high degree of heat subsequent at least to the formation of these compounds, and that the heating of meteorites during their fall to the earth has in many cases been only superficial.

The trails of light, sometimes enduring several minutes, observed following in the wake of some meteors may perhaps indicate the presence of carbonaceous matter in those bodies. The stone shower which took place at Hessle was accompanied by luminous effects and with the stones fell a brownish-black powder which contained 71 per cent. carbonaceous matter. Other carbonaceous meteorites have fallen, however, without exhibiting any marked luminous phenomena.

Other compounds.— Besides the above well-determined compounds a number of others have been reported at different times which are (1) present in insignificant amount or (2) their occurrence has not been confirmed, or (3) they may be of terrestrial origin. Among these a few may be mentioned: *Quartz.* This mineral, as is well known, is remarkable for its absence from meteorites. Yet it doubtless does occur in minute grains in a number of iron meteorites, since on dissolving them a residue is left, the grains of which possess the properties of quartz. Its occurrence in any stone or ironstone meteorite has never yet been established. *Pyrite.* This mineral has been reported a number of times, but sufficient proof to establish its identity has not been given. Von Siemaschko reported from the meteorite of Ochansk a brass-yellow pentagonal dodecahedron of which, however, he gave no measurements. Daubrée found in the meteorite of Senhadja, bronze-yellow grains insoluble in hydrochloric acid, soluble in aquaregia and altering easily to iron sulphate. While these and other observations suggest pyrite they are not conclusive. *Salts soluble in water.* Several of the carbonaceous meteorites as well as one or two others give

on evaporation of the water extract a residue of soluble salts reaching in quantity in one case as high as 10 per cent. of the mass. These salts include nickel, calcium, magnesium, potassium, sodium and ammonium sulphates and chlorides.

Since the meteorites in which they occur are very porous in character and show other signs of alteration these compounds are usually considered to be formed by terrestrial modification of the meteorite and not to exist as original constituents. Daubrée, however, gives good reasons for regarding the sodium chloride which he found in the Lancé meteorite an original constituent. These reasons are that the meteorite had lain only three days in a clayey bed before it was picked up and no salt is known to have come near it. *Breunnerite.* This mineral was found in the meteorite of Orgueil occurring in the form of little transparent crystals. The identity of the mineral was established both by qualitative tests and by goniometric measurements. It has been suggested that it was of secondary origin. As it was found well within the interior of some masses, this, however, hardly seems likely. This is the only carbonate known from meteorites.

A number of other minerals have been reported from meteorites without sufficient grounds, according to the writer's view, to support the conclusion. Cohen considers them doubtful while Meunier accepts most of them. These are: *Apatite, iolite, wollastonite, titanite, garnet, vesuvianite, mica, aragonite, leucite, cassiterite, hornblende, anthophyllite and orthoclase.*

Mineral aggregates.—The different aggregates which the compounds above described form in different meteorites are too various to be recorded here in detail. For an account of these, reference should be made to the elaborate classifications of Meunier,[1] Brezina[2] or Wülfing.[3]

A few general observations may be made here, however, following the lines of the classification given by Wülfing. The

[1] Revision des Pierres Météoriques. Paris, 1897.

[2] Annalen des k. k. Naturhistorischen Hofmuseums. Bd. X, Heft 3 u. 4. Vienna, 1896.

[3] Die Meteoriten in Sammlungen. Tübingen, 1897, pp. 447–460.

iron-meteorites, as already indicated, are made up chiefly of nickel-iron, with schreibersite, troilite, daubréelite and a few other minerals occurring as accessories.

Of the ironstone meteorites the largest quantity are of the so-called pallasites, formed chiefly of chrysolite and nickel iron. Nine falls of this group are known, having a weight of 1742 kilograms. In the group known as siderophyrs, represented by one fall (82 kilos), of meteoritic matter, bronzite and tridymite are associated with the nickel-iron. In the group of mesosiderites (grahamites) represented by ten falls (483 kilos), of meteoritic matter, the nickel-iron is accompanied by chrysolite, bronzite, plagioclase, and augite. In the group lodranite, composed of one fall with a weight of 1 kilo, chrysolite and bronzite are associated with nickel-iron.

Passing to the stone meteorites the following groups and weights may be noted:

A. Stones rich in calcium and magnesium and containing little or no nickel-iron.

1. Angrite. Chiefly augite. One fall, weight 0.4^{kg}.

2. Eukrite. Augite and anorthite. Four falls, weight 91^{kg}.

3. Shergottite. Augite and maskelynite. One fall, weight 5^{kg}.

4. Howardite. Augite, anorthite, bronzite, and chrysolite. Ten falls, weight 5^{kg}.

B. Stones rich in magnesia and containing little or no nickel-iron.

1. Bustite. Diopside and bronzite. Two falls, weight 1.7^{kg}.

2. Chassignite. Chiefly chrysolite. One fall, weight 0.9^{kg}.

3. Chladnite. Chiefly orthorhombic pyroxene. Four falls, weight 9^{kg}.

4. Amphoterite. Chiefly chrysolite and bronzite. Three falls, weight 40^{kg}.

C. Stones rich in magnesia and consisting essentially of chrysolite, bronzite, nickel-iron, and iron sulphide. Here belong the great majority of stone meteorites.

A comparison of the constituents as above described with those of the crust of the earth brings to view some interesting similarities and contrasts. Under *similarities* may be noted the fact that the elements of meteorites are the same as those of the earth and that they unite according to the same chemical and physical laws. No new element has been discovered in meteorites and the chemical compounds of meteorites similar to those of the earth agree even to the details of their crystal form.

Under *contrasts* it may be noted that two agents which have affected largely the composition of the crust of the earth have been lacking either wholly or in part in the formation of meteorites. These agents are water and oxygen. The lack of water is proved by the fresh and unaltered character of the minerals found in meteorites and the absence of all hydrous minerals. Thus the chrysolite of meteorites is never found serpentinized nor are the pyroxenes changed to chlorite nor the feldspar to kaolin.

Further, zeolites, micas, epidote, tourmaline and all other minerals in the formation of which water and water vapor play a part are entirely lacking from meteorites.

Similarity, oxygen, at least in excess, is lacking from the constituents of meteorites. Such substances as nickel-iron, schreibersite, and lawrencite, which make up so large a part of the composition of meteorites would rapidly have been oxydized had they been exposed to the action of oxygen as it occurs upon the earth. The silicates of meteorites are however oxydized compounds which show that oxygen is present to some degree in space.

Again, as noted by Cohen,[1] the important rock-forming minerals of the crust of the earth are either lacking or play an insignificant part in the formation of meteorites. Such are quartz, orthoclase, the acid plagioclases, the micas, the amphiboles, leucite, and nepheline. Vice versa, the chief mineral constitutents of meteorites occur in but insignificant amount upon the earth. Such are nickel-iron, the orthorhombic pyroxenes and chrysolite, while such compounds as schreibersite, cohenite, lawrencite, oldhamite, daubréelite and troilite rarely or never occur terrestrially. Looked at quantitatively then it may be said that terrestrial rocks abound in free silica, lime, alumina, and alkalies, while meteorites abound in iron, nickel and magnesia. Whether these quantitative differences would be maintained if the constitution of the earth as a whole could be compared with that of meteorites, is, as hinted at the beginning, doubtful.

OLIVER C. FARRINGTON.

[1] Op. cit., p. 323.

Among the innumerable phases of the great calamity which has fallen upon our country and the world in the tragic death of PRESIDENT MCKINLEY, the loss of a generous friend of science is by no means the least. The prosperity of the scientific bureaus under his administration has been as marked in improved organization and in method as in extension and in generous patronage, and the establishment of a new bureau in the interest of scientific and commercial precision is a laudable feature of special moment.

EDITORIAL

IN December, 1898, Mr. G. K. Gilbert presented to the Geological Society of America a paper upon ripple-marks and cross-bedding in which he undertakes to explain the large ripples of the Medina formation.[1] Mr. Gilbert became satisfied that these ripples differ "in no respect except size from the familiar ripple-mark of the bathing beach and the museum slab." In order to account for the size of some of the large ripples upon this theory he has inferred that the waves producing them were sixty feet high and made in "a large ocean."

In the July number of the *American Geologist*, Professor H. L. Fairchild objects to the deep ocean theory of the origin of these ripples, and brings evidence to show that they are beach structures.[2]

Without going into the details of either of the articles mentioned the present writer wishes to call attention in this connection to a paper upon the origin of beach cusps published in this JOURNAL (September–October, 1900, Vol. VIII, pp. 481–484), and to suggest that the explanation of the giant ripples spoken of by Gilbert and Fairchild is to be found in the seaward extension of beach cusps. The beach cusps are from sixty to eighty feet apart, from a few inches to three feet in vertical height and extend oceanward in approximately parallel lines. They are formed by the interference of two sets of waves of translation, and are therefore to be looked for not only on the beach where they appear at the water's edge, but as far out as the waves drag upon the sea bottom, and always pointing away from the shore. This theory appears to account readily for all

[1] Ripple-marks and Cross-bedding, by GROVE KARL GILBERT. Bull. Geol. Soc. Amer. Vol. X, pp. 135–140.

[2] Beach Structures in Medina Sandstone, by H. L. FAIRCHILD. Amer. Geologist, Vol. XXVIII, pp. 9–14.

the phenomena observed in connection with the ripples in the Medina without doing violence to the theory of the shallow water origin of those beds.

J. C. BRANNER.

THE experiment of holding the summer meeting of the American Association for the Advancement of Science as far west as Denver may be regarded as a success. The attendance compared favorably with what has previously been realized at several meetings in the interior, though for obvious reasons it was less than the attendance at meetings held in the more populous and accessible centers of the East. The papers and discussions, so far as one could judge from listening to those of a single section and from current opinion, also compared favorably with those of average meetings. There was less diversion from the specific purposes of the association by formal social functions which were few, and there was correspondingly greater real social intercourse between fellow scientists, because the intersessional intervals were more largely left free for this, a most laudable feature. The provisions for scientific excursions, at least in geologic lines, were notably more ample than usual and were arranged for the afternoons of the regular session, the morning sessions being extended to make this possible. The facilities for general and varied excursions at the close of the formal sessions were exceptionally generous. Only one feature of the general appointments and of the environment needs to be singled out for adverse comment, and that was the dreary silliness of the Denver press which, apparently recognizing its limitations in reporting appreciatively and intelligently the real scientific news, tried to make up for its inabilities by stale witticisms and coarse cartoons, interspersed with extravagant personal laudations of "the-greatest-scientist-on-earth" type. A few subjects relating to the economic interests of the region and to popular themes were, however, well reported.

The general addresses were excellent; that of retiring-President Woodward was an incisive and discriminating discussion of the progress of science, graced with an artistic marshaling

of lights and shadows as wholesome as it was skilful; that of Vice-President Van Hise on the philosophy of ore deposition was clear, strong and effective, and especially laudable, as a popular address in a mining region, for its unhesitating advocacy of the unpalatable as well as the acceptable phases of his doctrine.

Previous to the meeting a ten-day excursion of geologists was planned by Professors Van Hise and Emmons and carried out in a most admirable manner. The selection of routes and places from among the phenomenal possibilities of Colorado certainly made no small demands upon the knowledge and discretion of those in charge, but no whisper of a possible improvement was heard. The climax of interest was reached in the San Juan Mountains, where the exemplification of many and varied phases of geological phenomena from the Archean to the Pleistocene is marvelously impressive. The aid rendered by prominent citizens at various points visited and the generous hospitality extended to the party were beyond all praise. It would be a delight to acknowledge our obligations in special and individual terms, if, beginning with the exceptional courtesies of Walsh, Lay, and Freeland, it were possible to find an end of the list. About two dozen geologists participated.

The four geological sessions were crowded with papers well distributed over the various departments of geology and embodying much of exceptional interest and value. The papers read before the Geological Society of America, presented on the first morning, were as follows: "Account of the Geological Excursion," C. R. Van Hise; "Junction of the Lake Superior Sandstone and the Keweenawan Traps in Wisconsin," U. S. Grant; "Hydrographic History in South Dakota," J. E. Todd; "The Still Rivers of Western Connecticut," W. H. Hobbs; "Geology of the Northeast Coast of Brazil," John C. Branner; "Classification of the Geological Formations of Tennessee," James M. Safford; "Horizons of Phosphate Rock in Tennessee," James M. Safford.

The following papers were presented before Section E:

"The Effect of Diurnal Heat on Glacial Activity," J. F. Todd; "On Extra Terrestrial Stresses," E. Haworth; "On Stoping as a Factor in the Formation of Terraces," T. C. Chamberlin; "On Campodus, Helicoprion, Acanthus and other Paleozoic Sharks," Charles R. Eastman; "The Oscillations of the Coast Ranges of California," A. C. Lawson; "Some Features of the Geology of Golden, Colorado," H. B. Patton; "The Geological Occurrence of Oil in Colorado," A. Lakes; "Report on Some Studies Relative to Primal Questions in Geology," T. C. Chamberlin; "A Plea for Greater Simplicity in the Language of Science," T. A. Rickard; "Sandstone Intrusions near Santa Cruz, California," J. F. Newsome and J. C. Branner; "On the Pleistocene Deposits of Iowa," Samuel Calvin; "Problems of the Quaternary Deposits of the South Platte Valley," George L. Cannon; "Physiography of the Boston Mountains, Arkansas," A. H. Purdue; "Some Problems of the Dakota Artesian System," James E. Todd; "A Quantitative Study of Variation in the Fossil Brachiopod Platystrophia biforta, Schl.," E. R. Cumings and A. V. Mauck; "Interpretation of Some Drainage Changes in Southwestern Ohio," W. G. Tight; "The Minerals and Mineral Localities of Texas," F. W. Simonds; "The Minerals Associated with Copper in Southeastern Arizona and Southwestern New Mexico," G. H. Stone; "The Extinct Glaziers of New Mexico and Arizona," G. H. Stone; "Note on Certain Copper Minerals," A. N. Winchell; "The Areal Geology of the Castle Rock Region," W. T. Lee. The officers of the section were: C. R. Van Hise, vice president, and H. B. Patton, secretary. Those elected for the ensuing year are: O. A. Derby, of San Paulo, Brazil, vice president; and F. P. Gulliver, of Southboro, Mass., secretary. C.

Reviews

THREE PHASES OF MODERN PALEONTOLOGY

I. *Uintacrinus: Its Structure and Relations.* By FRANK SPRINGER. (Mem. Mus. Comp. Zoöl., Vol. XXV, pp. 1–90, 8 pls., Cambridge, 1901.)

II. *Oriskany Fauna of Becraft Mountain.* By JOHN M. CLARKE. (Mem. New York State Mus., Vol. III, No. 3, 128 pp., 9 pls., Albany, 1900.)

III. *Stratigraphical Succession of the Fossil Floras of the Pottsville Formation in the Southern Anthracite Coal Field.* By DAVID WHITE. (U. S. Geol. Surv., Twentieth Ann. Rept., Part II, pp. 749–930, 13 pls., Washington, 1901.)

Three notable contributions to our knowledge of fossil organisms have lately appeared from the hands of the printer. They are notable as making distinct advancements in paleontology. They are notable as typifying the three distinct phases into which the science relating to ancient life has finally resolved itself. They are notable as model works of their kind, each representing the general subject from a very different viewpoint, and hence show very diverse modes of treatment and the very diverse character of paleontological inquiry of today.

1. The crinoids have long been an attractive theme to geologists. Ever since the discovery by Marsh, in 1870, of the remarkable Cretaceous crinoid afterward called Uintacrinus, great interest has been taken by paleontologists in each new accession. Grinnell, Meek, Willison & Hill, and Logan, in this country, and in Europe, Schlüter and Bather, have described carefully the known material. It has remained for Mr. Springer, so long intimately associated with the lamented Wachsmuth, to give us a magnificent monograph on the subject, including a large amount of new information derived from rich, lately discovered material. And this after one would naturally think that about all that it was possible to say had been said.

The special charm and value in this work is the strictly morphological character that it presents. In this respect it fully keeps up the

same high standard of excellence that made the *North American Crinoidea Camerata* of Wachsmuth & Springer so acceptable to all students of fossil organisms.

Unusual interest centers in the composition of the base of Uintacrinus. A feature that has long been regarded as fundamental in the separation of the larger taxonomic groups is here found in one and the same species. "Considering the apparent identity of these forms in every other point of structure, coupled with their mode of occurrence and association, I do not see how such association [as made by Mr. Bather] can possibly be made in this case. We therefore have apparently to deal with a case of individual variation as to this supposed primitive character, within the limits of a species. That is to say, in this species, living in the same locality, having the same environment, floating in the same mass, certain individuals matured to represent one stage of larval development, *i. e.*, with infrabasals; and others in another stage, *i. e.*, with basals only.

In short, there are the two supposed distinct types, Monocyclica and Dicyclica, occurring in both young and adult of one and the same species. It will not do to say that the species is dicyclic, but in certain individuals the infrabasals are not developed, or are hidden by the centrale, or have disappeared by atrophy. If this were so, the centrale ought to be interradial in both cases; whereas, as already shown, its orientation is reversed from one to the other, precisely as in the typical monocyclic and dicyclic forms.

Such a condition is believed to be unique among the crinoids. The bearing upon certain recently proposed classifications of the crinoids is also important. Bather and Jaekel have both severely criticised Wachsmuth & Springer's classification and have erected schemes that are "sought by the modern biologist."

"There is no doubt," says Mr. Springer, "that each author who undertakes to express his ideas of descent in a new scheme of classification does so in the belief that his own structure is a substantial pyramid whose base is firmly established upon the ruins of the top-heavy contrivances of his predecessors. With regard to the crinoids, there have appeared, since our monograph of the Camerata, two elaborate classifications, each avowedly based upon phylogenetic principles, viz., that of Mr. Bather, already mentioned, and one by Dr. Jaekel, whose general researches and great works upon the crinoids of Germany constitute a rich contribution to science. The views of the latter author are to be developed in full detail in his magnificent

"Stammesgeschichte der Pelmatozoen," the first part of which, embracing the Thecoidea and Cystoidea, has just been published. He, likewise, finds fault with Wachsmuth & Springer, because, in his opinion, they have dealt with the morphological conditions as they found them too much from an anatomical standpoint, and have not sufficiently taken into account the import of the modifications due to descent. He finds in the changes in the systematic arrangement of the crinoids made by Wachsmuth & Springer in their successive writings, proof that the right road to the solution of the great questions of classification had not yet been found. We have, therefore, two new and almost simultaneous phylogenetic classifications, by two of the most eminent living authorities, both predicated in part upon the insufficiencies of Wachsmuth & Springer's system, and each believed by its author to be a new and correct reading of the race history of the crinoids. From such sources, and following such a preface, we should not unnaturally expect a brilliant illumination of the road, in search of which their predecessors have floundered in darkness. But to our dismay we find that instead of celebrating a conclusive settlement of these questions, we are only invited to witness fresh controversy. For these new chroniclers do not read their history alike, and their two classifications are about as diametrically and fundamentally opposite as anything could be."

Uintacrinus presents a striking resemblance to the living crinoid Actinometra in the eccentric position of its mouth, the central position of the anus, the absence of any calcified ambulacral skeleton on disk, arms and pinnules, the structure and distribution of the disk ambulacra, the form and proportions of brachials, and distribution of syzygies, the variable size of the anal tube, and the instability of the base.

The systematic position of Uintacrinus will be a matter of controversy for a long time to come. As yet hardly any two authorities agree in placing it in the same position.

Wherever it may belong, and whatever its line of descent, there is no doubt that Uintacrinus is both a protean and convergent form more remarkable than any we have hitherto encountered among the crinoids. Along with great variability in the base and interbrachial regions, it combines:

The interbrachial system and fixed pinnules of the Camerata;

The pliant test of the Flexibilia;

The large visceral cavity of both of these;

The exoclyclic disk and open ambulacara, and the arms, pinnules, and syzygies of Actinometra;

The free-floating character of the Comatulæ;

The dicyclic base of the Dicyclica;

The monocyclic base of the Monocyclica.

A noteworthy feature that should receive special mention in connection with this monograph is the distribution of study material, illustrating the points and structures discussed, to some of the principal museums. It is a feature that could well be imitated by other workers in paleontology. In this way the principal type specimens have been deposited in the Museum of Comparative Zoölogy. A large slab has been placed in the National Museum at Washington; it contains specimens exhibiting most of the characters discussed. A fine series of specimens have also been sent to the British Museum, and to the Royal Museum of Natural History at Berlin, where they will be accessible to European students.

2. As stated by Dr. Clarke, in his prefatory note to the *Oriskany Fauna of Becraft Mountain*, the original purpose of his work was solely to depict the character and composition of the Oriskany fauna of Becraft Mountain, which of itself displays many features of interest. In its progress, however, various questions have arisen which concern the intrinsic value of the fauna and its importance in correlation. Yet without an understanding of the fauna itself it would be impracticable to discuss the latter problems, and for this reason the title of the paper is restricted to the principal argument of the work, to which the discussions of a somewhat broader scope are corollaries.

A fauna which finds its highest development at Becraft Mountain, near Hudson, in Columbia county, N. Y., links together in the character of its species, the calcareous shales and limestones of the Lower Helderberg and the normal Oriskany sandstone.

The interesting bearings of this assemblage of species, its new forms and new associations and its real importance in the correlation of the Lower Devonian are sufficient reason for presenting its characteristics in detail.

A brief account of the stratigraphy of the mountain is given, and also the general New York section as recently revised. Accompanying these is a small geological sketch-map of the Becraft Mountain syncline.

The greater portion of the memoir is devoted to the description of species, which are finely illustrated by nine plates of figures. A table of the vertical range of species occurring in the region is given.

With our present knowledge there are thus 113 recognizable, distinct specific forms in the fauna of the Oriskany at Becraft Mountain, and of these 94 are identifiable with species already known or are clearly new forms peculiar to the fauna. Of the 94, 25 preceded the introduction of the Oriskany sedimentation, having been first described from the fauna of the Helderbergian. In the arenaceous beds of the Oriskany 23 occur; 10 range upward into the faunas of the Upper Helderberg (Ulsterian), but a part of these are restricted to the sandy, lower beds of this formation (Schoharie grit), and others have been noted only in the chert beds of Ontario, Canada, where the intermixture of Oriskany and Onondaga species is well marked and has been recorded by Schuchert. The fauna contains 35 species which so far as known are peculiar to it. On farther analysis of the table, it is evident in some cases that species which range down and upward are restricted to particular groups. Thus the alien trilobites are from the Helderbergian; the gasteropods are exclusively Oriskany; while the alien lamellibranchs are mostly Helderbergian. But the leading factor of the fauna, the brachiopod, has its derivation as freely from below as in the Oriskany invasion.

The faunal values of the different species are then summed up.

Concerning the nature of the Oriskany fauna of New York, the author says:

The fauna of the calcareous Oriskany is in no sense a mixed assemblage, or an intermingling of faunas of adjacent provinces. The sequence of life has continued without interruption from the Helderbergian (Kingston beds) into the sediments of the Oriskany and Onondaga limestone.

It is extremely probable that important variations from the fauna of the Catskill shaly (New Scotland) limestone had already made their appearance in the Becraft limestone, and that we first become acquainted with some of these in the study of the calcareous Oriskany. No proof therefore could be adduced more emphatically confirmatory of the intimate faunal relations of the Helderbergian with the Oriskany fauna and its successors than the facts brought forward in this paper.

The fauna discussed is that of the calcareous facies of the Oriskany formation. The sedimentary deposits of this and the neighboring sections were essentially limestones notwithstanding the silicious content, whether diffused through the mass or segregated as cherty secondary product. In the earlier presentation of this fauna it was regarded as of lower Oriskany horizon on account of the presence of many Helderbergian species, but we believe it will be more correctly construed as the representative of the proper and normal Oriskany fauna, the true fauna of this time-unit inclosed in the sediments of its proper habitat.

A chapter is devoted to discussing the Devonic age of the Helderbergian fauna and the base of the Devonic system in New York.

The fact of the presence of numerous Helderbergian species in the fauna of the Oriskany of Becraft Mountain, as an integral part of that fauna, not a casual intermixture, is sufficient demonstration that the fauna of the Helderbergian became modified in its continued existence by the departure or extinction of certain of its species only. A fair percentage kept the field up to the time of and pending the incursion of species of the early Oriskany. In this way the former became a true and proper part of this new fauna with whose indicial species it coexisted throughout the remainder of its duration. A modification so gradual as to permit such an uninterrupted existence cannot sever the close relation of the one fauna in its entirety to the other. It is therefore a natural corollary from the account given of the Oriskany fauna, to consider briefly the relation of the organic assemblage constituting the typical and normal Helderbergian to the Devonic type of organic life, and that formation in its relation to the Devonic system.

Arguments are adduced from the intrinsic characters of the fauna, from correlation, and from stratigraphy.

3. Of very different nature is Mr. White's work on the plants of the Pennsylvania Coal-measures. The stratigraphical interval which he considers is occupied by the Pottsville formation, Pottsville series, or Pottsville conglomerate. It is described as a series of largely arenaceous beds of variable thickness which in eastern Pennsylvania lies between the Maunch Chunk red shale, or distinctly Lower Carboniferous, and the lower productive Coal-measures, or distinctly Upper Carboniferous.

The investigation was intended to establish three propositions: (1) The exploitation and elaboration from, a stratigraphic standpoint, of the fossil plants of the Pottsville formation in the type region of the southern anthracite coal field; (2) the critical analysis and comparative study of the plant material collected, with a view to the discovery of the existence of any natural paleontological subdivisions, zones, or horizons, and their paleontologic characters, or the species of stratigraphic value; (3) the discovery of the paleontologic limits as differing or as agreeing with the lithologic limits of the type section, and the consequent paleontologic definition of the formation.

The main aim of the investigation is the paleontologic definition of the terrane.

Two other, largely concomitant, results that are either economic or scientific in their nature have also been reached in the process of the elaboration of the fossil plants of the formation in the typical region. The first, of some economic interest, is the correlation of the groups of beds, or of individual

coals wrought in disconnected or somewhat isolated portions of the southern anthracite field. The other, which concerns the question of general geological correlation, is the acquisition of data for the determination of the age of the Pottsville formation—*i. e.*, (*a*) the time interval represented by the type section, and (*b*) the equivalents, in a broad sense, of the formation in other basins of this province and in other parts of the world. Incidentally also, through the discovery in the Pottsville of floras already more or less completely known from isolated and uncorrelated terranes in other regions of the United States, the way is opened to the proper reference and correlation of those terranes with the Pottsville, or with portions thereof.

As introductory to the consideration of the plant remains as a means of geological classification there are presented a sketch of the general geological structure of the southern anthracite coal field, a description of the Pottsville formation in the typical locality, the composition of the formation, the coals contained, and their commercial names as guide horizons.

A type paleobotanic section of the Pottsville is then discussed, and the groupings of beds are enumerated. The various species and their observed distribution within the formation and in the field is given in detailed tabulated form, in which all the species are listed, together with their respective ranges. The floras of the several subdivisions indicated are discussed in some detail. The correlative comparison of the horizons of the southern field with those of the other anthracite fields is of special interest.

A considerable portion of the memoir is devoted to the description of the most characteristic species of plants found in the Pottsville, and to notes on many other species.

One of the most surprising, as well as interesting, facts observed in the study of the Pottsville floras is the large element that is common in the latter and to the flora described by Sir William Dawson from the supposed Middle Devonian beds of St. John, New Brunswick. In fact, taking into view the entire flora of the Pottsville formation in the Appalachian province, the identities in the composition of the floras are so great, with respect to both genera and species, as to leave little room for doubt that we have in the "Fern Ledges" at St. John beds of nearly the same age as the Pottsville formation in Pennsylvania. On the whole, while recognizing in the Pottsville formation a group of terranes equal in rank to the Lower Coal-measures, Alleghany series, etc., I do not favor a classification which relegates the entire formation hard and fast to the Upper Carboniferous, but I even anticipate a possible necessity for its permanent division into two groups, the lower

of which may eventually perhaps be referred to the Lower Carboniferous. From a paleobotanic standpoint the Pottsville formation is the beginning of Mesocarboniferous.

Briefly stated, the following are some of the general conclusions reached:

No evidence of a marked or general unconformity between the Pottsville and Mauch Chunk is noticeable in this region, though at various points within several hundred feet of the strata beds of small bowlders or coarse conglomerates are imposed, in knife-edge contact, on the distinctly uneven surfaces of olive-green mud-beds.

The flora in the roof of the Buck Mountain coal, or its supposed equivalents, at the base of the Lower Coal-measures at Pottsville is a typical Coal-measures flora, very distinct from the floras typical of the Pottsville formation.

The fossil plants of the Pottsville formation in the type region exhibit a rapid development and series of changes or modifications, which, if treated with great systematic refinement, are of high stratigraphic value. With the exception of the species from the topmost beds of the formation, the ferns are, in general, readily distinguished specifically from those at the base of the Lower Coal-measures, or Alleghany series, as recognized in the northern United States, while the floras of the lower portions of the section are found, in passing downward, to bear still less resemblance to those of the Lower Coal-measures. Two principal divisions of the formation, to which comparatively few fern species are common, are recognized. These divisions, which coincide with the natural grouping of the Lykens coals, are here termed the Lower Lykens division and the Upper Lykens division. A portion, including about two hundred feet of the type section between these two paleontologic divisions, contains a mixed flora, and has been temporarily designated the Lower Intermediate division.

Further paleontologic study of the Pottsville formation appears to fully confirm the earlier conclusion, based on the examination of the plants, that the thinner sections of the formation along the northern and western borders of the Appalachian trough do not contain beds as old as those in the lower portion of the thick sections along the eastern border, *e. g.*, in the Schuylkill and Great Flat Top regions. The positions of the respective floras in the sections plainly indicate a transgression of the sea toward the north and west during Pottsville time.

Both lithologically and paleontologically the Pottsville formation constitutes a division of the Carboniferous coördinate with the Lower Coal-measures, Alleghany series, etc. As such it forms the lower member of what may in a broad sense, be termed the Mesocarboniferous in the Appalachian province.

The lowest beds in the thickest sections, which appear to be continuous by transition with the deposition of the Maunch Chunk red shales, are perhaps to be regarded as coarse, coast-detrital redepositions, contemporaneous with the uppermost beds of the red shale or marine Lower Carboniferous sediments of other regions.

The flora of the Pottsville formation is so far identical, in both its generic and its specific composition, with that from the supposed Middle Devonian beds at St. John, as to leave no room for a great difference in the age of the latter.

CHARLES R. KEYES.

Iowa Geological Survey; SAMUEL CALVIN, State Geologist; A. G. LEONARD, Assistant State Geologist; Annual Report for 1900 (Vol. XI, 519 pages, 12 plates, 43 figures, 9 maps. Des Moines, 1901).

In scope and style this report follows closely the previous volumes of the series. It includes the usual administrative reports, the statistical reports of the mineral production, and detailed reports on Louisa, Marion, Pottawattamie, Cedar, Page, and Clay and O'Brien counties, the last two being treated together. These reports are written by J. A. Udden, B. L. Miller, J. A. Udden, W. H. Norton, Samuel Calvin, and T. H. Macbride respectively. They contain a careful review in each case of the local geology and serve to put on record facts and observations which may be used in later discussion of the theoretical problems involved. Following the usage of the survey, these discussions are taken up as fast as the development of the general survey allows them to be intelligently discussed. In the case of Louisa county, for example, the problems of the drift of that region have already been discussed in their theoretical phases in Mr. Udden's report on Muscatine county, Mr. Norton's report on Scott county, and Mr. Leverett's well-known monograph.[1] In the Louisa report Mr. Udden gives many interesting and valuable details confirmatory of the

[1] U. S. Geol. Surv., Mon. XXXVIII. The Illinois Glacial Lobe.

general conclusions already reached. In the Cedar county report, on the other hand, Mr. Norton places clearly before the reader the facts as to the structure and situation of the beautiful land forms to which McGee has given the name *paha*, and also states the various hypotheses which have been suggested for their origin. He makes no attempt, however, to balance the probabilities and reach a decision in the matter. The same method is observed in the discussion of the high dips observed in the Gower limestone of the Niagara. This is confessedly a difficult problem, and its solution is wisely left until the whole area shall have been studied.

In the reports on Page and Pottawattamie counties the survey takes up the southwestern portion of the state. Apparently most interesting results are likely to follow this survey. Mr. Calvin's suggestion that the drift of Page county may be the pre-Kansan instead of the Kansan fits in with many of the known facts of the field in Iowa and neighboring states. It is a far-reaching suggestion, and the development of the hypothesis will be watched with interest. In Pottawattamie county the facts are possibly susceptible of either interpretation. Mr. Udden does not, however, discuss the probabilities. His report is particularly interesting to the general student in the large use which he makes of mechanical analyses in the study of the drift. This is a method which seems likely to become more and more useful in the study of unconsolidated materials. The important results already reached by Whitney in the study of soils seem merely the forerunners of what is possible on a wider application of the method to the study of geological problems in general. Mr. Udden's hypothesis of the origin of the rivers of the county is ingenious, but the argument is not altogether convincing. The suggestion that the surface of a great ice sheet would afford a better opportunity for the development of such a regular system of rivers than the drift surface left by the melting away of the ice seems open to question. The surface of the Kansan drift, it is true, is everywhere notably even. It is impossible, however, to suppose that so thick and widespread a drift sheet as this would be laid down without the development of moraines and other surface irregularities. Yet such irregularities, where they now occur, are very faint, and are apparently the marks of much greater original irregularities. The present plane surface seems likely to be a result of erosion itself. Remembering the long period since these older drifts were deposited and the manifestly great erosion to which they have been subjected, it

seems a bit fanciful to believe that the streams now have a general course originally developed on the top of the ice. It is also difficult to imagine how streams, granting that they were developed on the ice in a symmetrical fashion, could be transferred to the drift surface during the melting of the ice without disturbance of their arrangement. If the disappearance be supposed to be accomplished by frontal retreat, the edge of the ice itself will give a sufficiently marked line for the development of the cross streams, and the major streams would in all probability be developed normal to the ice front. This apparently accords with the facts of the field and does not involve the difficulty of accounting for the development of a vigorous surface drainage on the ice and its transfer to the drift surface without notable destruction of its arrangement. The whole problem is an interesting one, and certainly Mr. Udden's hypothesis, if valid, is widely applicable. If we are to be able from the present stream arrangement to infer so much regarding the condition during glacial times a considerable step in advance is made. This fact warrants the closest skepticism in examining the hypothesis.

The volume as a whole is one which geologists will welcome. While the long series of annual reports made up of separate county reports is confusing to one not familiar with the region, the survey is systematically building up a work which will prove valuable not only to students of the local geology but to geologists in general. The work will lend itself to final summary treatment, and in the meantime the county reports not only serve a useful purpose locally, but enable outsiders to keep in touch with the results. The progress map of the drift mapping (plate II) is particularly valuable in this regard.

H. F. B.

Beach Structures in the Medina Sandstone. By H. L. FAIRCHILD. American Geologist, Vol. XXVIII, pp. 9–14, plates 2–6.

In the July number of the *American Geologist* Professor H. L. Fairchild discusses the "Beach Structures in the Medina Sandstone." The features considered are certain troughs and swells of a breadth ranging from thirty to eighty feet. These are assumed to be of the same nature (probably in some cases the same examples) as those which formed the basis of Dr. Gilbert's theory of "giant ripples." Gilbert had concluded (*Bulletin Geol. Soc. Amer.*, March 1899) that with

"certain combinations of amplitude and frequency" the largest ocean waves might produce ripples having a length equal to half the height of the wave. The supposed giant ripples observed at Lockport, N. Y., reached a length of thirty feet, implying waves sixty feet high in the Medina sea. Fairchild explains the same features as spits or rather beach ridges, sometimes observed in series of as many as four crests with intervening troughs. Of the fifteen halftones with which the article is illustrated, about one third are clear enough to show without doubt that the features referred to are of the same nature as those discussed and figured in Gilbert's article. Four of the cuts show sand ridges on the present shore of Lake Ontario which are supposed to exemplify the process by which the features in the Medina were made. The remaining cuts and a few expressions in the article leave it in doubt as to whether the features observed were all of the type from which Gilbert's conclusions were drawn. The latter found no intervals of more than thirty feet from crest to crest; the article under discussion refers to similar spacings of eighty feet. Gilbert's discussion of the features as ripples implies a symmetry or at least unity in the trough by which its breadth could be fairly estimated when only a portion could be seen. Fairchild speaks of the trough as only a "negative or passive element" which may have any width varying with the accidents which determine the location of a new beach ridge. The observations of both, and both interpretations, involve abundant cross bedding. It would seem that the two processes hypothesized would produce different dispositions of this crossbedding, as well as differences in the symmetry of the trough. Gilbert shows by diagram the necessary arrangement of the crossbedding under various suppositions as to the shifting of the ripple system during deposition. It is quite improbable that the patterns in vertical cross section thus produced would be duplicated in a series of beach ridges. In the latter case the lamination on the landward side of an outer ridge should be plainly distinguishable from the lamination on the lakeward slope of the next ridge within. The lamination corresponding to this latter slope should disappear only in the most extreme cases of landward migration of the ridge, a condition quite improbable where a series of ridges is produced. Fairchild's objection that ripple marks are not found of intermediate sizes between eight inches and the "giants" is certainly of interest.

N. M. F.

The Beaufort's Dyke, off the Coast of the Mull of Galloway. By H G. KINAHAN. Proceedings of the Royal Irish Academy, Third Series, Vol. VI, No. 1.

In the Proceedings of the Royal Irish Academy, Third Series, Vol. VI, No. 1, Mr. H. G. Kinahan, District Surveyor (Retired), H. M. Geological Survey, describes "The Beaufort's Dyke, off the Coast of the Mull of Galloway." This "dyke" is a deep trough in the bed of the Irish Sea nearer the coast of Scotland. The plate accompanying the article reproduced from the Admiralty charts, shows a long line of soundings of 100 to 148 fathoms, surrounded by a comparatively level bottom 70 or 80 fathoms deep. Attention is just now directed to these depths by the proposition to construct a tunnel from Scotland to Ireland. The geological interest lies in the fact that in this trough "there are sands, gravels and their adjuncts, at depths of from 120 to 144 fathoms that are carried backward and forward similarly to those on an ordinary sea beach." This is much deeper than the waves and currents even on most exposed coasts have been supposed to act. The vigor with which this deep washing occurs may be inferred from figures given in a table, which show that at one point the bottom was cut down by erosion from a depth of 117 fathoms to a depth of 146 fathoms from 1894 to 1897 or nearly 60 feet a year. At other times filling was similarly rapid. The origin of the dyke or trough itself is left in doubt but faulting and glacial action are suggested. The origin of currents capable of acting at that depth is the main subject of interest. It is assumed that while the effect of wind waves and tide waves is reduced to zero at moderate depths there are deep currents induced by these superficial waves, to the depth of whose action no definite limit is assigned. The author contrasts these currents with the ordinary tidal races which may be supposed to erode shallow places more than deep ones. He refers to his former publications for detailed proof that denudation by these currents in question "is in ratio to the depth of the water." The whole article goes to show that when the movements of water are controlled by channels or reflected from irregular shores, the coarseness of the sediments at given depths bears little relation to the mathematically computed power of the water for those depths.

N. M. F.

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